PRACTICAL ZOOLOGY

HEGNER

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PRACTICAL ZOOLOGY

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PRACTICAL ZOOLOGY

BY

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PREFACE

THIS book is intended for the use of students in secondary schools. It includes sufficient material for an entire year's work, but certain chapters or parts of chapters may be eliminated if less time is available. The large number of chapters and their short length make elimination easy and also facilitate the assignment of lessons. For example, the book may be adapted for a half year course by omitting chapters III, XII, XIV, XVI–XVIII, XX–XXIV, XXVIII, XXX, XXXV, and XXXIX. The word "practical" in the title has been chosen since an effort has been made to present those facts and theories about animals which will have the most practical bearing upon the daily life of the student. It refers not alone to the economic side of the subject but also to the elements that are of greatest intellectual value.

Ideas differ considerably as to what constitutes the best course in zoology for secondary schools, but we cannot be far wrong if we succeed in combining a general knowledge of animals and of zoological principles with a discussion of the relations of animals to man, in such a way as to *interest* the students. The constant references to the relations of animals to their environment and the selection of common animals, especially those of economic importance, for illustrative purposes tend to stimulate the natural interest of boys and girls in animal life.

Many of the illustrations are from photographs which show the living animals in their natural environment. Next to the animals themselves, photographs of this kind furnish the best idea of the species studied. The drawings representing anatomical structures have been selected so as not to duplicate those called for in the laboratory manual.

The directions for field and laboratory work have been grouped together in a separate booklet, thus making it easy for the teacher to assign lessons or modify the work. This also makes unnecessary the presence of textbooks in the laboratory. Throughout both the laboratory manual and the textbook a too rigid plan has been avoided, and it is therefore expected that each teacher will be able to express his own ideas regarding the sequence of subjects and the phases of the work to be emphasized.

ROBERT W. HEGNER.

ANN ARBOR, MICHIGAN,
January, 1915.

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PRACTICAL ZOOLOGY

CHAPTER I

WHERE ANIMALS LIVE

If we compare the structures of our bodies, the food we eat, the way we move from place to place, and our various other activities with those of the apes, such as the gorilla, chimpanzee, and orang-utan, we become aware of many similarities. If we continue the comparison with other animals, for example, cattle, sheep, horses, dogs, cats, etc., we realize that they possess structures and carry on activities which resemble in a general way those of the apes and man. Likewise the birds, snakes, turtles, frogs, and fish have many peculiarities in common with other animals and with us.

Besides these animals, every one is more or less familiar with many of what we call the " lower animals," especially insects, snails, oysters, earthworms, starfishes, tapeworms, and jellyfishes. All of these animals must be able to live amid their surroundings; that is, in their natural habitat, and to reproduce others to continue the race after they are dead so that their kind may not disappear entirely from the earth. In order to live, human beings, as well as all the other animals, need certain things. The most important needs for the maintenance of life are food, water, air (oxygen), protection, and an opportunity to reproduce. These needs are satisfied by different kinds of animals in different ways, and the variety of structures employed for satisfying these needs and the methods used seems almost infinite.

We are accustomed to think of other animals as living on land

the way we do, and it is true that most of those we encounter in our daily lives are terrestrial in habit; but we should remember that human beings, miners, for instance, may live underground for long periods of time, or may remain in the water for hours without injury, or may even move through space in a balloon or aëroplane. These departures from activities on the earth's surface are, however, only temporary, and man's habitat is to be considered purely terrestrial.

Human beings share their *terrestrial habitat* with most four-footed beasts, with the frogs and toads part of the time, and with a host of the lower animals, such as insects, spiders, and certain snails and worms. Fortunately, land animals do not all try to live in the same sort of habitat, but are distributed over the entire earth's surface. Some seem to prefer the cold polar regions, others temperate or tropic zones; some inhabit the open plains, others live on forested mountains; and even the height above sea level has an influence upon the kind of animals inhabiting any particular area. Animals that live on the surface are better known than those that live in the ground, since the latter are less often seen. Among these ground inhabitants or subterrestrial animals are the earthworm, and many other worms, certain insects, crayfishes, and spiders, some of the snakes, a few birds like the burrowing owl, and a number of quadrupeds, of which the pocket gopher, mole, woodchuck, and prairie dog are common examples. Almost all of these animals must come to the surface from time to time to get food and for other purposes, but their true homes are in the ground.

The animals of another group spend a part of their time flying about in the air; to these the name *aërial* has been applied. The most notable aërial animals are the birds, flies, butterflies, and other insects, but there are a few flying quadrupeds, the bats, and a few animals like the flying squirrels, flying lizards, and flying fish, which do not really fly but only spread out the membranes with which they are provided and sail through the air for comparatively short distances.

If animals were entirely restricted to the land for their homes, only a comparatively small part of the world would be inhabited, since about three fourths of our globe is covered with water. Most of this is sea water, which contains about three and one half per cent of salt, whereas a comparatively small area is covered by the fresh water in lakes, ponds, and streams. A study of the animals that live in *sea water* and in fresh water soon reveals the fact that, with few exceptions, those accustomed to salt water perish almost at once if transferred to fresh water, and *vice versa*, those living normally in fresh water die very quickly if placed in the sea. Thus are the habitats of animals strictly limited. Some of the common animals that live in the sea are whales, sea turtles, many fish, a host of crabs, lobsters, and similar forms, cuttlefishes, oysters, many clams and snails, some worms, the starfish and its near relatives, the jellyfishes, corals, sponges, and thousands of different kinds of minute animals that can be seen clearly only with the aid of the microscope.

Since most of us do not live on the seacoast, we are naturally more familiar with the animals that live in *fresh water*. Fish, crayfish, aquatic insects, the young of the mosquito, and the tadpoles of frogs and toads are abundant fresh-water forms. They do not, however, occur everywhere, but each kind of animal is restricted to a rather definite habitat. For example, some fish live in only the deepest parts of lakes, others prefer slow-flowing streams, and many select the rapid waters of rivers and brooks. Similarly, with other fresh-water inhabitants, each has its own sort of habitat from which it very seldom strays.

This might seem to complete the list of available habitats for animals, but there is one mode of existence that from the standpoint of human welfare is probably more important for us to know about than any other. This is the parasitic existence led by thousands of forms, like the tapeworm, liver fluke, hookworm, and trichina, and that vast army of invisible foes called germs which are responsible for such diseases as malaria and yellow

fever in man and Texas fever in cattle. These *internal parasites* live within the bodies of the particular animals upon which they prey, and must be adapted to the conditions there; for example, the tapeworm and the hookworm amid the digestive juices in the alimentary canal of man, and the malarial parasite in the blood of man. Other parasites are said to be *external*, since they do not penetrate into the body, but simply ride about on their victim. Human beings are sometimes infested with external as well as internal parasites; we need only mention the louse and the flea. Even parasites are sometimes attacked by other parasites, thus establishing the truth of the following lines: —

> "Great fleas have little fleas
> Upon their backs to bite 'em,
> And little fleas have lesser fleas,
> And so *ad infinitum*."

The relations between animals and their surroundings are often very complex. Living creatures must not only be able to cope with the state of temperature, moisture, and other physical conditions of their habitats, but must also maintain more or less complex relations with plants, other animals of the same kind, and animals different from themselves. There is always a *struggle for existence* among the lower animals, just as there is among human beings who work so strenuously for homes and power. In this struggle for existence the weak usually succumb and as a result the strength of the race is maintained. One curious fact is that other animals may depend upon, as well as struggle with, one another. This may best be illustrated by Charles Darwin's story of the field mice and humble bees. Darwin found "that the visits of bees are necessary for the fertilization of some kinds of clover; for instance, twenty heads of Dutch clover yielded 2290 seeds, but twenty other heads, protected from bees, produced not one." . . . "Humble bees alone visit the red clover, as other bees cannot reach the nectar, — hence we may infer as highly probable, that, if the whole genus of humble bees became extinct or very

rare in England, the heart's-ease and red clover would become very rare, or wholly disappear. The number of humble bees in any district depends in a great measure upon the number of field mice, which destroy their combs and nests. . . . Now the number of mice is largely dependent, as every one knows, on the number of cats. . . . Hence it is quite creditable that the presence of a feline animal in large numbers in a certain district might determine, through the intervention first of mice and then of bees, the frequency of certain flowers in that district!" The influence of old maids upon the number of cats was suggested by Huxley as an addition to Darwin's illustration.

Not all of the kinds of animals that exist at the present time have been studied and named. There are many forms in every locality that have thus far escaped the scientist, and there are vast regions of the earth's surface, both land and water, that are yet to be examined. Nevertheless at least *five hundred thousand different kinds of animals have been described.* It is obvious that we can learn about only a few of this vast number. Fortunately, it is possible to group these animals into large assemblages because of certain common characteristics; and these assemblages can be subdivided into smaller groups. For example, all animals with a long axis, like the human backbone, are placed in one group, the vertebrates. One of the subdivisions of the backboned animals contains about eight thousand different kinds of animals which possess hair and are called mammals; the mammals may again be divided into smaller groups, one of which includes man.

In this way order has been introduced into what would otherwise be a very chaotic mass of isolated items of knowledge, and by selecting a few members from each assemblage or subdivision we can get a very good general idea of the entire animal kingdom. This is what we propose to do in the following chapters, and our selection will include those animals that we are most likely to meet on our way to and from school or on our trips into the country, and those that are of particular importance to man

either because of their use in industries or of their less direct beneficial or injurious qualities. Furthermore, by directing our attention to certain aspects of the life histories and activities of these animals we shall obtain a general knowledge of the laws and principles involved in the study of animals, the study known as *Zoology*. Throughout our study, however, we should not lose sight of the fact that *we ourselves are animals*, and that the needs of the living creatures which we dominate are similar to our own needs although the methods of satisfying them may be very different. An animal must be adapted to the conditions within its habitat or it cannot maintain itself. In our studies, therefore, we must learn how the animal is adapted to its particular set of conditions before we can solve the problems involved.

Finally, there is one phase of animal study that has only recently been emphasized, and that is the relation of animals to the community, state, and nation. This subject, which is rather fully treated in this book, we may call "Civic Zoology."

It will be necessary in the following chapters to speak of certain of the large assemblages of animals, and for this reason a simplified classification is here appended. It is not intended that the student should learn the following classification, but he should use it as a convenient and simple reference. It is often advisable to separate the entire animal kingdom into two subkingdoms, the Invertebrates and the Vertebrates, because of the relative importance of the latter. The Vertebrates possess a backbone; the Invertebrates do not. These subkingdoms may then be divided into eight groups called phyla. The phyla are arranged, from the simplest to the more complex. The numbers refer to the number of known kinds of animals in each phylum.

Subkingdom I. Invertebrata. — Animals without backbones. 518,400.

Phylum 1. Protozoa. — Minute, single-celled, or colonial animals. 8500.

Phylum 2. Porifera. — SPONGES. 2500.

Phylum 3. Cœlenterata. — JELLYFISHES, POLYPS, and CORALS. 4300.

Phylum 4. Platyhelminthes. — TAPEWORMS, FLUKES. 4600.

Phylum 5. Nemathelminthes. — THREADWORMS. 1500.

Phylum 6. Annelida. — SEGMENTED WORMS. 4000.

Phylum 7. Echinodermata. — STARFISHES, SEA URCHINS. 3000.

Phylum 8. Mollusca. — CLAMS, SNAILS. 60,000.

Phylum 9. Arthropoda. — CRABS, INSECTS, SPIDERS. 400,000.

SUBKINGDOM II. VERTEBRATA. — Animals with backbones. 30,000.

Phylum 10. Vertebrata. — FISHES, AMPHIBIANS, REPTILES, BIRDS, MAMMALS. 30,000.

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CHAPTER II

THE GRASSHOPPER

The Habits, Physiology, Anatomy, and Economic Relations of a Typical Insect

About four fifths of the five hundred thousand different kinds of animals known to man belong to a single group which we call insects. Not only are insects numerous, so far as the number of kinds is concerned, but there is an abundance of individuals of each kind. This abundance makes it possible for us to collect them without difficulty, and hence it is easy to obtain material for our studies. Besides this, many insects, such as butterflies and beetles, are very beautiful; they are also wonderfully adapted to their various habitats, and when collected and properly arranged in a cabinet make one of the most interesting and instructive exhibits of natural objects that it is possible to possess. Furthermore, certain insects, like the honeybee and silkworm, are of great commercial value; the gipsy moth, potato beetle, chinch bug, army worm, and thousands of others must be continually fought to prevent the destruction of our crops; and certain kinds, the house fly and mosquito, for instance, are the principal cause of the transmission of diseases like typhoid fever, malarial fever, and yellow fever.

When we have learned the general structure and functions of the parts of an insect, it is an easy task to distinguish these animals from all others; and such a study lays the foundation which will help us to understand the activities of other kinds of insects and the structures concerned with these activities. In selecting an insect for this first study we should try to find one large enough

to be examined easily, at least with a pocket lens, and one that is comparatively simple in structure. For this reason we shall use the grasshopper for our preliminary study. The grasshopper is one of the largest of our insects as well as one of the simplest in structure. Grasshoppers are abundant during most of the year and are therefore easily obtained for use in a laboratory.

FIG. 1. — Carolina locust. (After Lugger.)

Grasshoppers or "locusts" are common everywhere in the fields and meadows, jumping out of the way of an intruder or sometimes flying up when approached. They may be collected by a quick grasp of the hand or hundreds can be caught in a short time in an insect net. Methods of locomotion can be studied both in the field and in the laboratory, but the structure can only be made out with a quiet, therefore, a dead specimen. Insects can be killed painlessly by means of a cyanide bottle, and preserved in 80 per cent alcohol. Grasshoppers resemble one another in general structure, the different kinds differing only in details, so the following account will apply to almost any of them.

Locomotion. — WINGS. — Insects are the dominant animals at the present time, so far as numbers are concerned — a fact that is due to many causes. One of these causes is their ability to move rapidly from place to place which enables them to find food easily and to escape from their enemies. The locomotor

organs are the wings and legs. Some insects, like the bedbug and the flea, are without wings and depend entirely upon their legs for purposes of locomotion; whereas others, as the butterflies, make flight their chief method of progression. The grasshopper uses both wings and legs, but the latter are more effective during the ordinary activities of daily life. Both wings and legs are attached to the middle of the three principal parts of the body; a part called the thorax (Fig. 1). The four wings are arranged in two pairs fastened by movable joints at the sides near the upper surface. The front pair are rather leathery in structure, serving as a protection for the thin, membranous back wings, which are folded beneath them when at rest. The thin wing membranes are strengthened by minute tubes which are definitely arranged in every wing and are similar in number and position in the individuals of every kind of insect but different in the different kinds.

FLYING. — The movements of the wings during flight are quite interesting. The front edge of the wing is firm, whereas the membrane as a whole inclines upward when the wing is lowered, and downward when the wing is raised. This results in resistance from behind, which propels the insect forward. The wings on opposite sides of the body move up and down together, and the faster they vibrate the more rapidly the insect progresses. The house fly makes 330 strokes per second, the dragon fly 28, and the cabbage butterfly 9.

LEGS. — The six legs of the grasshopper are arranged in three pairs; one pair is attached to each of the three parts or segments which make up the thorax. Other insects are likewise provided with three pairs of legs. The legs are used by insects chiefly for locomotion, but also for many other purposes, and an examination of their structure will often enable us to determine their functions (Fig. 2). Some are long and slender and fitted for running (Fig. 2, *b*); others are flattened out and bordered with bristles, making them effective swimming organs (*e*); some are short and shovel-shaped for digging in the earth (*d*); a few enable

their possessors to grasp their food (*a*); and a number of kinds, like the hind legs of the grasshopper (*c*), are longer and stronger than the others and especially adapted for leaping.

Each leg is made flexible by a number of joints which divide it into distinct segments. These segments have all been given names which are important for two reasons: (1) they are often descriptive of the part named, and (2) they enable us to talk and write about the various parts intelligently. The segment of the leg attached to the body is called the coxa; the next is the trochanter; then follows the long slender femur; then the tibia with spines on its inner surface; and finally the tarsus. The tarsus consists of three distinct segments, but the one next to the tibia really represents three that are fused together. If the undersurface of this segment is examined, three pads will be found, each belonging to one of the fused segments. There are therefore five tarsal segments — the usual number in all insects. The final tarsal segment bears a pair of curved claws which make it possible for the grasshopper to cling to rough objects, whereas the pads on the underside of the tarsal segments enable the animal to walk on smooth surfaces. The pad belonging to the last tarsal segment lies beneath the claws. Of particular interest are the two hind legs of the grasshopper, since these

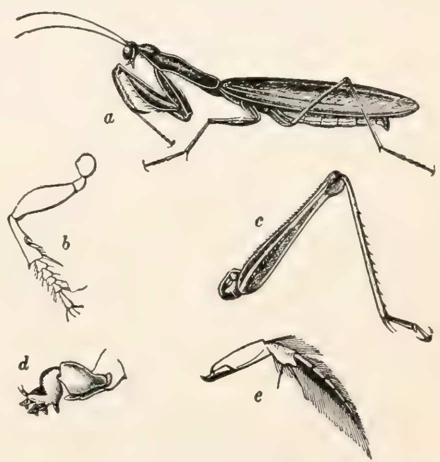

Fig. 2. — Legs of insects showing relation between structure and function.

a, grasping leg of praying-mantis; *b*, running leg of a beetle; *c*, leaping leg of a grasshopper: *d*, digging leg of mole-cricket; *e*, swimming leg of beetle. (After Sedgwick.)

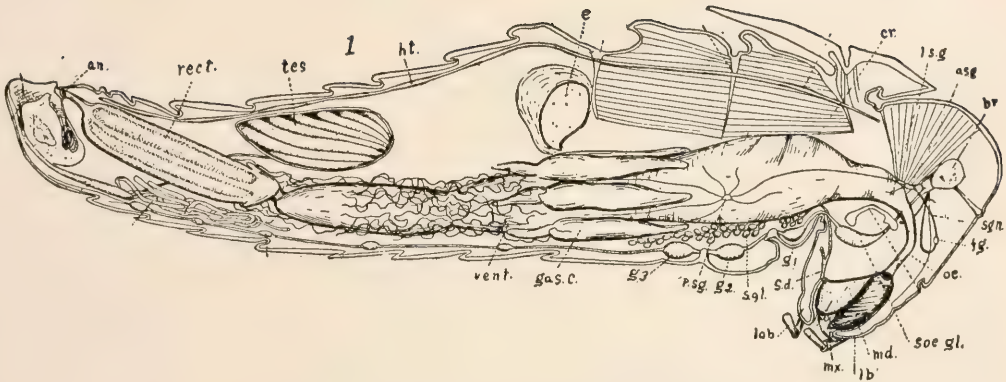

FIG. 3. — Internal anatomy of the Carolina locust.

an, anus; *br*, brain; *cr*, crop; *e*, ear; *g. 1*, *g. 2*, *g. 3*, thoracic ganglia; *gas.c*, gastric cæca; *ht*, heart; *lab*, labium; *lb*, labrum; *md*, mandible; *mx*, maxilla; *oe*, œsophagus; *rect*, rectum; *s.d*, salivary duct; *s.gl*, salivary gland; *tes*, testis; *vent*, ventriculus or stomach. (After Snodgrass.)

are used for leaping. They are built on the same plan as the others, but the femur is very much enlarged, to accommodate the muscles which are used when the animal jumps.

Food and Mouth Parts. — Grasshoppers feed on all sorts of plants and possess a set of rather complicated mouth parts for holding and grinding up pieces of vegetation. These mouth parts are movably attached to the underside of the head. The food is held by an almost rectangular flap, in front, and a bilobed flap, behind, which are known as the upper lip or labrum (Fig. 3, *lb*) and lower lip or labium (Fig. 3, *lab*). Between these flaps are two pairs of grinding organs, the true jaws or mandibles (Fig. 3, *md*), which consist each of a single thick piece and are grooved, and the auxiliary jaws or maxillæ (Fig. 3, *mx*) which are made up of several pieces and serve principally to hold the food between the mandibles. Both the labium and maxillæ bear short, jointed filaments which are supplied with organs of taste, touch, or smell. By means of these organs the insect is able to choose between the available food material. Biting mouth parts, such as those of the grasshopper, are the simplest sort found among insects.

Digestion. — While the food is being masticated by the jaws, it is mixed with a secretion (saliva) produced by a pair of salivary glands (Fig. 3, *s.gl*); this secretion passes out through a salivary duct (Fig. 3, *s.d*). The saliva acts upon the starch in the food, changing it into a more digestible substance called glucose — a change very similar to that which takes place in our own digestive process. The masticated food mixed with saliva then enters the alimentary canal. This is really a tube which runs through the body and is separated into several well-marked regions by constrictions.

First, the food passes through a small tube, the œsophagus (Fig. 3, *œ*), into a large thin-walled portion, the crop (Fig. 3, *cr*); here the saliva continues its action upon the starchy materials in the food. In most insects the crop is followed by a thick grinding organ lined with teethlike projections, but this is ab-

sent in the common Carolina locust. Next, the partially digested food enters the stomach or ventriculus (Fig. 3, *vent*), where it is acted upon by juices secreted by six spindle-shaped pouches (Fig. 3, *gas.c*) which open into the anterior end of the stomach. From the stomach food passes into the intestine (not all of this is shown in Fig. 3), the final portion of which is known as the rectum (Fig. 3, *rect*). The digested food is absorbed by the walls of the alimentary canal and the undigested material passes out of the body through the anal opening (Fig. 3, *an*).

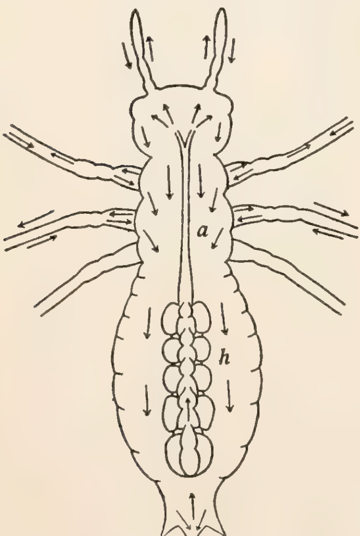

Fig. 4. — Diagram of an insect showing the heart (*h*), aorta (*a*), and direction of the blood-flow (by arrows). (After Kolbe.)

Circulation. — The digested food absorbed by the intestinal wall enters the blood which fills the body cavity, and is carried in the blood stream to all parts of the body, where it is assimilated; that is, is changed into living matter to take the place of that which is continually being used up by the activities of the animal. The blood is a fluid containing corpuscles. These corpuscles are not reddish in color, as in human beings, but are usually colorless. The fluid of the blood is also generally colorless, but it is sometimes yellowish or greenish. It has just recently been discovered that the sex of many young insects (caterpillars) can be determined by the color of the blood, that of the males being yellow, and that of the females green.

The circulatory system of the insect is very simple and there

is no complex arrangement of tubes, as in human beings. Near the upper part of the body is a rather long contractile tube called the heart (Fig. 3, *ht*), into which the blood surrounding it flows through pairs of openings. By contractions, the blood is forced forward out of the heart and into the spaces of the body in which the various internal organs lie. All of these organs are in this way continually bathed with a fresh supply of blood, as illustrated by the arrows in Figure 4.

FUNCTIONS OF BLOOD. — In man the blood carries food material, waste substances, and oxygen from one part of the body to another, but in insects there is a complex system of tubules, known as tracheæ, which carry oxygen directly from the outside to the various parts of the body and so the blood is relieved of this duty.

Respiration. — We are accustomed to think of breathing as taking place through the nose or mouth, but in insects air is taken in through pores, called spiracles, or stigmata, which occur at intervals on the sides of the body. The grasshopper is provided with ten pairs of these breathing pores; two in the thorax and eight in the abdomen. Connected with these openings are the tubes within the body which branch many times, becoming very minute. The taking in and forcing out of air, a process known as respiration, is brought about by regular expansions and contractions of the abdomen. In certain grasshoppers there had been found to be from thirty-four to ninety-two respiratory movements per minute. Such a system as that just described is in the grasshopper and many other insects assisted by rows of air sacs; thus an abundant supply of oxygen is assured at all times, a fact that in part accounts for the remarkably rapid growth of these animals.

Excretion. — Waste matters in solution that result from the breaking down of the living matter during the activities of the insect are collected by a group of long thin tubes which are coiled about in the body cavity (Fig. 3) and enter the forward end of the intestine. These tubes, of which there may be as many as

one hundred and fifty in the grasshopper, perform functions similar to those of the kidneys of other animals. They are known as Malpighian tubes, being named after the Italian naturalist, Malpighi (1628–1694).

In the preceding paragraphs we have described many of the processes that take place within the body of an insect. This study of function is known as physiology. We have also discussed the organs concerned with these processes; the study of structure constitutes the science of morphology. There are still, however, several systems of organs which perform functions necessary for the insect to cope successfully with its surroundings. These are concerned with protection (exoskeleton), the reception and transmission of stimuli (sense organs and nervous system), and the continuity of the race (reproductive system).

Protection. — The outside covering of the grasshopper and other insects, the exoskeleton, is known as the cuticula and consists of a substance called chitin. Chitin protects the insect from mechanical injury as well as from contact with water and other liquids. It is formed by the part of the living matter just beneath it. This chitinous covering may be assisted by hairs, scales, and spines which, however, may serve other purposes as well as that of defense. Frequently the exoskeleton is colored in such a way as to conceal the insect amid its surroundings; this is known as protective coloration. For example, a green katydid is difficult to see when resting on a green leaf. As a further means of protection some insects possess glands which produce evil-smelling or distasteful substances sufficient to prevent attacks from dangerous birds and lizards.

Sensations. — Insects, like human beings, receive impressions from the outside world by means of special structures called sense organs. We may distinguish organs of sight, touch, smell, taste, and hearing. These organs are scattered about on various parts of the body and connected with the central nervous system, but the most important ones are borne by the head.

The *visual organs* comprise two compound eyes (Fig. 1) and three simple eyes or ocelli. The compound eyes are built up of hundreds of similar parts, each of which forms a portion of an image and thus all together they produce a sort of mosaic. The ocelli probably serve chiefly to distinguish light from darkness.

The organs of *touch*, *taste*, and *smell* are represented by various forms of bristles which usually lie in minute cavities and are connected with the nervous system. Tactile or touch bristles and often olfactory or smelling organs are located on the antennæ, whereas those concerned with taste are, as might be expected, distributed over the mouth parts.

The grasshopper has besides all these a pair of very interesting auditory or hearing organs situated one on either side near the forward end of the abdomen. They consist of a light membrane so constructed as to vibrate, and receive and transmit sound waves. These auditory organs enable the grasshoppers to communicate with each other; thus the male Carolina locust is often seen poising in the air with rapidly vibrating wings, and making a crackling sound by rubbing the front and hind wings together.

Nervous System. — The stimuli received by the sense organs are carried to the central nervous system by means of nerves, and impulses are sent out by the central nervous system in the same way. The insect in this manner becomes aware of the conditions of its surroundings, and the impulses sent out result in appropriate movements. The nervous system is essentially a double thread united at intervals by a mass of nervous substance called a ganglion. The brain (Fig. 3, *br*) is the foremost mass of this sort. From the brain one part of the double thread passes down on either side of the œsophagus and unites below with another ganglion (Fig. 3, *soe. gl*). Then follows a chain of eight ganglia lying near the lower part of the body in the median line. Those in the thorax (Fig. 3, *g. 2*, *g. 3*) are the largest of these, since they must control the wings and legs. The delicate sympathetic nervous system (Fig. 3, *asg*, *fg*, *lsg*, *psg*, *sgn*) con-

trols the swallowing movements, regulates digestion and breathing, and controls the salivary glands and circulation.

Reproduction. — Grasshoppers do not live very long and the race must therefore be continued from year to year by the production of new individuals. The processes involved are those connected with the formation of eggs and the development of the eggs and young until the adult stage is reached. The eggs, or female germ cells, arise within the egg tubes of the female insects. Before they are laid they are penetrated by the

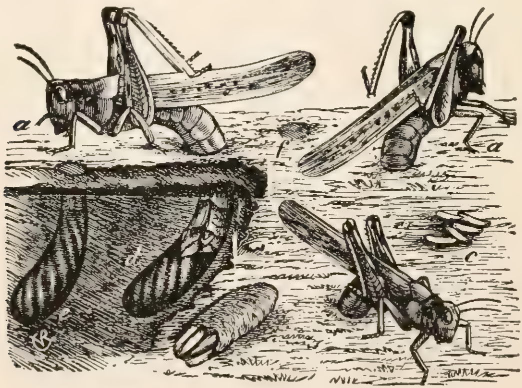

FIG. 5. — Rocky Mountain locusts laying eggs. (After Riley.)

male germ cells which arise in the reproductive organs of the male (Fig. 3, *tes*); this union of male and female germ cells is known as fertilization. During July and August these eggs are formed into masses of from thirty to one hundred, covered with a sort of jelly, and deposited in a hole in the ground about an inch below the surface (Fig. 5). Here they remain throughout the winter. The following spring the young emerge from the egg in a form resembling their parents in many ways, but differing from them in the size of the head and absence of wings (Fig. 6). As the young grow, the exoskeleton becomes too tight for them, so they shed it (molt) at intervals and acquire a new

one. At each molt the shape of the body changes and the wings, which soon appear, grow larger, until finally the adult condition is reached (Fig. 6, *6*). The changes that occur during this period of growth constitute what we know as metamorphosis, and the young in the case of the grasshopper is known as a nymph.

Metamorphosis. — The development of the insect within the egg, a study called embryology, is too complex to be considered here, but we can discuss with profit the growth of the young

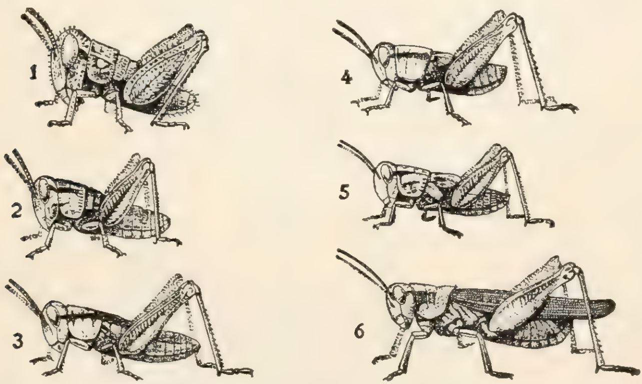

Fig. 6. — Six successive stages in the metamorphosis of a grasshopper. (After Emerton.)

after they hatch and the changes that take place from this time until the adult condition is reached.

A few wingless insects (*Aptera*) emerge from the egg in the form of the adults and do not change much, except in size, throughout life. Another larger group, of which the grasshopper is an excellent example (Fig. 6), hatch as nymphs, resembling their parents in general form, but thereafter undergo various changes until they have reached their full size. This is *direct metamorphosis*, the term direct referring to the fact that there are no interruptions due to resting periods, but the insects are active throughout life. The majority of insects, however,

undergo *indirect metamorphosis*. They hatch from the eggs as wormlike larvæ, grow in size for a time, and then enter a stage of rest, when they are spoken of as pupæ. During the pupal stage the adult insect develops within the pupal covering and finally breaks out fully formed. The larvæ of butterflies and moths are called caterpillars; those of beetles, grubs; and those of flies, maggots. The pupæ of butterflies and moths are popularly known as chrysalids. The chrysalis is often covered by a cocoon spun by the larva.

Relations to Man. — Grasshoppers are valuable for the purpose of studying structure and function. They are important also because of the injuries they inflict upon crops in order to satisfy their hunger. There are plenty of noxious weeds that the grasshoppers might devour with benefit both to themselves and to the farmer, but they persist in destroying many kinds of useful plants instead.

The most notorious grasshoppers in this country are the Rocky Mountain or migratory locusts. These insects were particularly destructive in the states of the western part of the Mississippi Valley in the years 1873 to 1876. Their native breeding grounds are in the highlands of Montana, Wyoming, and Colorado, but when the locusts become excessively abundant, they spread eastward, flying with the wind, as much as two hundred or three hundred miles in a single day. Their ravages in the seventies were described by a commission of men appointed by Congress to report upon them as follows: —

"Falling upon a cornfield, the insects convert in a few hours the green and promising acres into a desolate stretch of bare, spindling stalks and stubs. . . . Their flight may be likened to an immense snow-storm, extending from the ground to a height at which our visual organs perceive them only as minute, darting scintillations, leaving the imagination to picture them indefinite distances beyond. . . . In alighting, they circle in myriads about you, beating against everything animate or inanimate, driving into open doors and windows, heaping about

your feet and around your buildings, their jaws constantly at work, biting and testing all things in seeking what they can devour."

Since then Rocky Mountain locusts have appeared at intervals in destructive numbers in Minnesota, North Dakota, and neighboring states, but have never been a real plague. Practically nothing can be done to prevent the injuries done by such vast hordes of migrating insects.

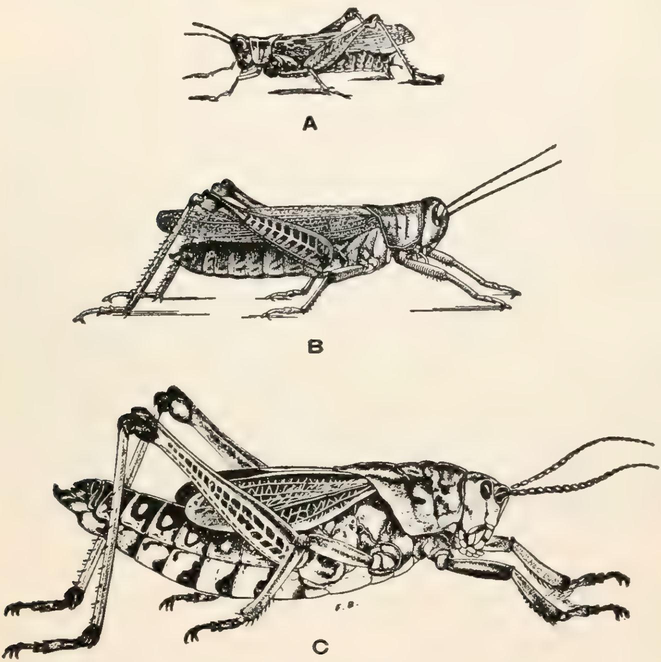

FIG. 7. — Three grasshoppers injurious to vegetation.
A, Red-legged locust. (After Riley.)
B, Differential locust. (After Sanderson and Jackson.)
C, Southern lubber grasshopper. (After Sanderson.)

Other grasshoppers, though not so notorious as the Rocky

Mountain locusts, are of considerable economic importance, appearing in some localities every year in such abundance as to become very destructive to crops. Of these may be mentioned the red-legged locust of the eastern United States (Fig. 7, A), the California devastating locust in California, the differential locust of the Mississippi Valley (Fig. 7, B), the huge lubber

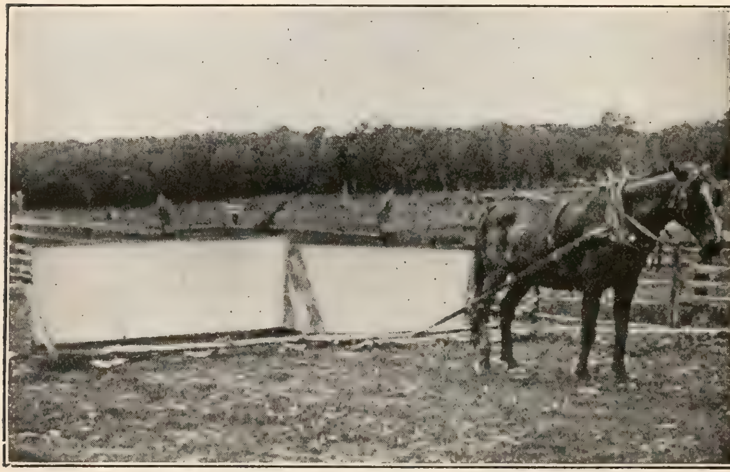

Fig. 8. — Two hopperdozers, tied together, at work. (After Lugger.)

grasshoppers of Florida and the Western plains (Fig. 7, C), and the American acridium of the Southern States.

Several methods of controlling these non-migratory locusts have been devised; fall plowing buries their eggs so that they do not produce young; poison bran mash may be scattered in the fields to kill both young and adults; and a contrivance called a hopperdozer (Fig. 8) catches thousands of leaping individuals in its pans of kerosene as it is dragged over infested fields.

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CHAPTER III

SOME INSECT ADAPTATIONS

OUR knowledge of the activities of the grasshopper and the structure of this insect will enable us to understand the modifications that serve to adapt other insects to their various modes of life. The number of these adaptations is legion and we shall therefore have to select a few of the most interesting ones that can be observed in the laboratory.

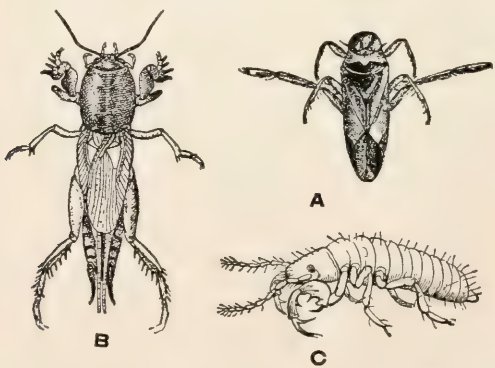

FIG. 9. — **A**, a back-swimmer. Notice the oar-like hind legs. (After Weed.)
B, a mole-cricket with front legs fitted for digging. (After Barret.)
C, young of the Cicada with front legs fitted for digging. (After Marlatt and Riley.)

Locomotion. — First, as regards locomotion, we may refer to the insects that spend their lives in the water or underground. Many aquatic insects are excellent swimmers, with legs specially constructed for use as oars. This is true of the whirligig

beetles, diving beetles, and back swimmers (Fig. 9, A). Insects like the mosquitoes (Fig. 53) and the water skaters, on the other hand, remain on top of the water, where they are sustained upon the surface film by their long slender legs, just as is a needle which is carefully placed on top of the water in a tumbler. Insects that burrow in the ground possess legs fitted for digging; for example, the mole-cricket (Fig. 9, B) and the young of the cicada (Fig. 9, C). Many insects, like the flea (Fig. 32), do not fly because they lack wings, but others cannot fly even with wings, either because these organs are too small for the weight of the body (Fig. 26) or, as is the case with some beetles that are found under stones and logs, their wings have grown together so that they cannot be spread.

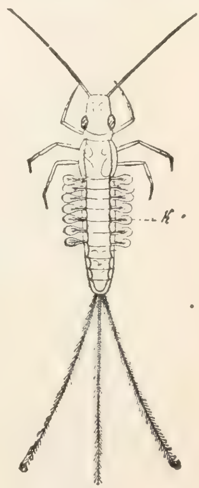

FIG. 10. — Young of may fly showing tracheal gills (*k*). (After Sedgwick.)

Respiration. — The breathing methods or respiration of aquatic insects are often very different from those of their relatives living on land. Since these insects live under the water, they must either come to the surface for air (Fig. 55), or else get their air from the water. Many of them, like the young of the may flies (Fig. 10) and damsel flies, possess filamentous or leaf-like projections called tracheal gills, by means of which the air mixed with water is collected in the air tubes and then carried throughout the body.

Securing Food. — MOUTH PARTS. — Adaptations for the purpose of getting food are especially important, since those insects with biting mouth parts, like the grasshopper, can be destroyed by spraying their food with a poison such as Paris green; whereas those with piercing and sucking mouth parts feed only on juices from within the plants or animals they attack, and must be destroyed in some other way. The mouth

parts of the mosquito (Fig. 11, A) may serve as an example of the sucking mouth parts. The upper and lower lips form a tube in which the long, sharp mandibles and maxillæ move when a puncture is made. The juices are drawn into the alimentary canal by the suction caused by a muscular enlargement of the œsophagus. In some sucking insects there is a special reservoir, called a sucking stomach

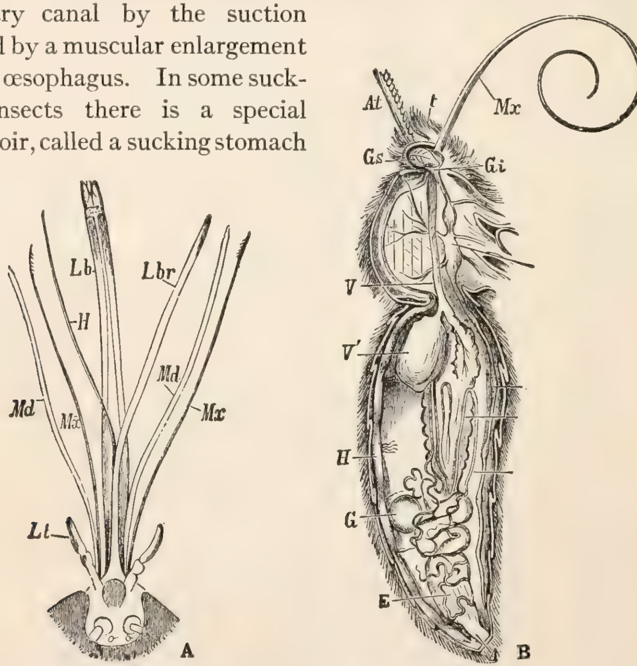

FIG. 11.—**A**, mouth parts of a mosquito.
H, hypopharynx; *Lb*, lower lip; *Lbr*, upper lip; *Md*, mandible; *Mx*, maxilla. (After Becker.)
B, internal anatomy of a moth showing the proboscis (*Mx*) and sucking stomach (V′). (After Newport.)

(Fig. 11, B, *V′*), in which juices are stored until needed. The sucking apparatus of the butterflies and moths differs from that of the mosquito. Here the maxillæ are very long, forming a tubelike proboscis (Fig. 11, B, *Mx*) which is coiled beneath when not in use, and the jaws are extremely small or entirely absent.

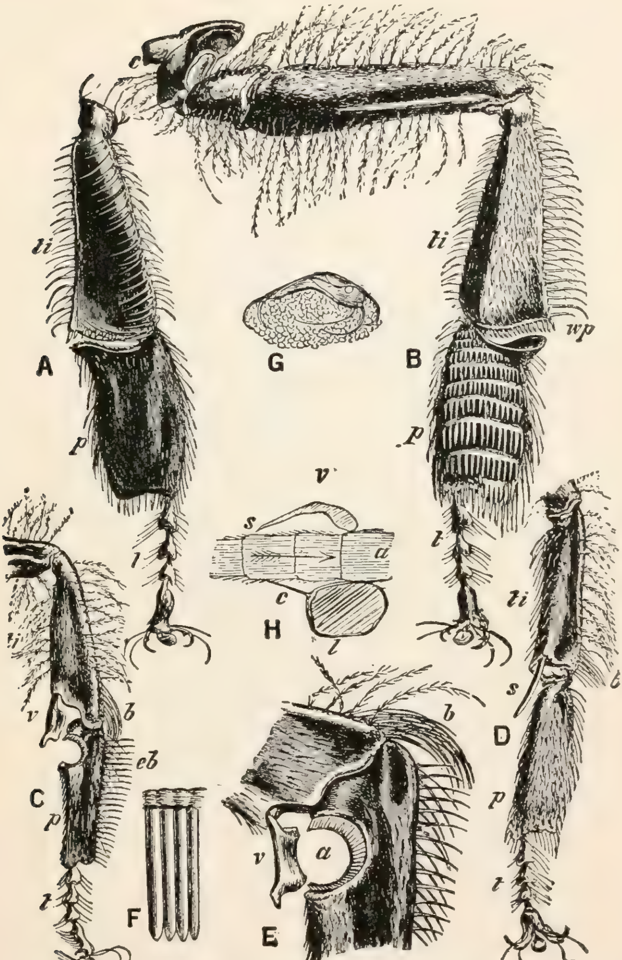

FIG. 12. — Legs of the worker honey-bee. (After Cheshire.)

LEGS. — Among the most interesting of all adaptations for food-getting are those exhibited by the legs of the worker honey-bee. These are shown in Figure 12 and may be described

briefly as follows: The first pair of legs (Fig. 12, C) possess the following useful structures. The femur and the tibia (*ti*) are clothed with branched hairs for gathering pollen. From the distal end of the tibia of one of these is the pollen brush (*b* in C and E), the curved bristles of which are used to brush up the pollen loosened by the coarser spines; on the other side is a flattened movable spine, the velum (*v* in C and E), which fits over a curved indentation in the first tarsal joint or metatarsus (*p* in C). This entire structure is called the antenna cleaner, and the row of teeth (F) which lines the indentation is known as the antenna comb. Figure H shows in sections how the antenna (*a*) is cleaned by being pulled between the teeth (*c*) on the metatarsus (*l*) and the edge (*s*) of the velum (*v*). On the front of the metatarsus is a row of spines (*eb* in C), called the eye brush, which is used to brush out any pollen or foreign particles lodged among the hairs on the compound eyes.

The middle legs (Fig. 12, D) are provided with a pollen brush (*b*), but, instead of an antenna cleaner, a spur (*s*) is present at the distal end of the tibia. This spur is used to pry the pollen out of the pollen baskets on the third pair of legs and to clean the wings.

The last pair of legs (Fig. 12, A and B) possess three very remarkable structures, the pollen basket, the wax pinchers (*wp* in B), and the pollen combs (at *p* in B). The pollen basket consists of a concavity in the outer surface of the tibia with rows of curved bristles along the edges (*ti* in A). By storing pollen in this basketlike structure, it is possible for the bee to spend more time in the field, and to carry a larger load each trip. The pollen basket in cross section is shown in Figure 12, G. The pollen combs (at *p* in B) serve to fill the pollen baskets by combing out the pollen which has become entangled in the hairs of the thorax, and transferring it to the concavity in the tibia of the opposite leg. At the distal end of the tibia is a row of wide spines; these are opposed by a smooth plate on the proximal end of the metatarsus. The term wax pinchers (*wp* in B)

has been applied to these structures, since they are used to remove the wax plates from the abdomen of the worker. All of these structures can easily be observed in the laboratory with the aid of a microscope.

FIG. 13. — **A**, Kallima, the leaf-butterfly, flying; *a*, at rest. **B**, Siderone, another leaf-butterfly, flying; *b*, at rest. (From Davenport.)

Coloration. — Finally, insects, as well as many other animals, are often adapted to their surroundings by their colors. Colors are very highly developed among insects, and while some do not seem to be of any particular use to their possessors, it is easy to determine the distinct value of others. Many insects, both

adults and young, in general resemble their surroundings. Thus the green caterpillar of the cabbage butterfly (Fig. 20) is very difficult to see against the green of the leaves and no doubt escapes from many of its enemies because of its *general protective resemblance.*

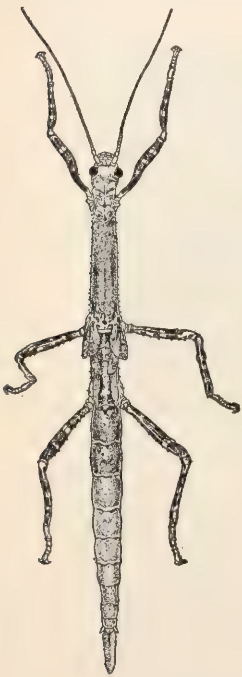

FIG. 14. — A walking stick. (From Davenport.)

One of the most famous of all butterflies is the Kallima (Fig. 13) which is found in India. When at rest this insect clings to the side of a twig with its wings held together over its back. In this position it resembles a dead leaf and is no doubt overlooked by its enemies, the birds and lizards. Any animal that looks like some special object, as in this case, is said to possess *special protective resemblance.* An interesting insect of this sort that is often abundant in this country is the walking stick (Fig. 14), which is long and slender and colored like the bark of a tree. When it clings to a twig and extends its front legs in a line with its body, it is effectively concealed from its enemies by its special resemblance to the twig.

Certain other animals are very brightly colored and are, therefore, quite conspicuous amid their surroundings. It has been found, however, that such animals are often distasteful to their natural enemies, and, being conspicuous, are readily recognized, and thus the animals that might otherwise prey upon them are warned of their inedible qualities. The potato beetle, the ladybird beetle, and the hornet are all supposed to be *warningly colored.*

The term *protective mimicry* has been applied to cases such

as that of the relation between the milkweed butterfly and its near relative the viceroy butterfly. The milkweed butterfly seems to be inedible to birds and is warningly colored. Its cousin, the viceroy, which is eaten by birds, resembles the milkweed butterfly so closely that one must examine the two with care to distinguish one from the other. The viceroy is supposed to mimic its larger relative and thus escape by being mistaken for its inedible model.

Sometimes the colors of an animal are not only protective but *aggressive*, since they effectively conceal their owner while it is creeping upon its prey. A green snake among green leaves can thus get close to its victim without being seen. No sure cases of aggressive coloration are known among insects.

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CHAPTER IV

INSECTS INJURIOUS TO VEGETATION

Extent of Injury. — People who live in towns and cities occasionally hear of the destruction to crops caused by such insects as the army worm and chinch bug, and notice the fact that the leaves of trees are sometimes eaten away by beetles and caterpillars. Most of them do not realize, however, that every kind of crop raised by the farmer, every kind of fruit tree cultivated by the fruit grower, and every sort of forest and shade tree is constantly being attacked by destructive insects and their value considerably lessened on this account. We suffer financially because the smaller crops cause higher prices, and when we learn that about 10 per cent of every crop is destroyed by insects, we can estimate in a general way how much we spend annually in feeding these voracious creatures. The average annual damage done by insects to crops in the United States was conservatively estimated by Walsh and Riley to be $ 300,000,000 — or about $ 50 for each farm. A recent estimate by experts puts the yearly loss from forest insect depredations at not less than $ 100,000,000. The common schools of the country cost in 1902 the sum of $235,000,000, and all higher institutions of learning cost less than $ 50,000,000, making the total cost of education in the United States considerably less than the farmers' loss from insect ravages. It costs the American farmer more to feed his insect foes than it does to educate his children.

Furthermore, the yearly losses from insect ravages aggregate nearly twice as much as it costs to maintain our army and navy, more than twice the loss by fire, twice the capital invested in

manufacturing agricultural implements, and nearly three times the estimated value of the products of all the fruit orchards, vineyards, and small fruit farms in the country.[1]

A

B

Fig. 15. — **A**, moth of the army worm. **B**, the army worm. (After Riley.)

Even after the crops are harvested they are still open to the attack of meal worms and other insects that feed on stored grain and manufactured food-stuffs.

There are many thousands of insects that deserve to be mentioned, but our space is limited and we must therefore refer to only a few that affect us most directly. Each sort of plant is infested with many kinds of insects, but usually only a few of these are very destructive. Thus corn is attacked by about two hundred different insect enemies, clover by a like number, apple trees and apples by four hundred, and oak trees by probably a thousand.

A B C D

Fig. 16. — The chinch bug: **A**, adult; **B**, nymph; **C**, eggs (enlarged); **D**, beak through which the bug sucks its food. (After Riley.)

Army Worm. — We often read in the daily papers or in gov-

[1] Folsom, J. W., *Entomology* with reference to its biological and economic aspects.

FIG. 17. — Chinch bugs on a corn plant. (Photo by O'Kane.)

ernment bulletins of the insects that are destructive to field crops, such as the army worm and the chinch bug. The army worm (Fig. 15, B) is a black and yellow striped caterpillar about one and one half or two inches long when full-grown. It is the larval stage (caterpillar) of an inconspicuous dull-brown moth (Fig. 15, A). These caterpillars may occur anywhere east of the Rocky Mountains and sometimes become so abundant that they must migrate in search of food. At such times they crawl along in vast armies feeding, usually at night, upon the leaves and stalks of grains and grasses, the heads of which they generally cut off. The crops over large areas are in this way totally destroyed, with a tremendous loss to the farmer and indirectly to the final purchaser of the food manufactured from grain.

METHODS OF CONTROL. — Fortunately army worms are killed in enormous numbers by their natural enemies or they would soon make the world uninhabitable. The tachina flies (Fig. 47, B) are their worst enemies. These little insects lay their eggs on the body of the army worm (Fig. 47, C) and the maggots which hatch from these eggs burrow into the worm and finally kill it.

The most effective method of protecting a field from invasion is to plow a deep furrow with steep sides around it and then pulverize the soil in the furrow so that the worms cannot climb out. As a result they collect in the bottom, where they can be crushed or killed by a dose of kerosene.

Chinch Bug. — Another important enemy of field crops is the chinch bug (Figs. 16 and 17), an insect about one fifth of an inch long, with a black body and white wings folded over the back. This insect has been principally injurious to small grains and corn in the Central and North Central States, the total damage during the years 1850 to 1909 being estimated at $350,000,000. The bugs travel from field to field on foot, although they possess wings, and like the army worm may be stopped in their march by a steep furrow plowed in their path. A narrow strip of coal tar is also an effective barrier to their progress.

Other Insects Injuring Field Crops. — Other notorious pests of field crops are the grasshoppers (see Chap. II); the cutworms (Fig. 18, A), which have a habit of gnawing off the stems of plants just at the surface of the ground; the Hessian fly (Fig. 18, B), which attacks the stalks of wheat and causes an average loss of about 10 per cent each year; the green bug (Fig. 18, C), a plant louse which sucks the juices of oats, wheat, barley, and corn, stunting or killing the plants; the corn-ear worm (Fig. 18, D), which eats into the ears of corn, destroying from 2 to 3 per cent of the crop annually with an estimated cash value of from thirty to fifty million dollars; the alfalfa weevil (Fig. 18, E) in the West; and the cotton boll weevil (Fig. 18, F) of the South, which damages cotton every year to the extent of about twenty million dollars.

Insects Injuring Garden Vegetables. — POTATO BEETLE. — We are perhaps more familiar with insects that injure garden vegetables, such as the potato beetle and cabbage butterfly, than with those that destroy field crops. The potato beetle (Fig. 19) was, up to the year 1885, a harmless insect, living in the Colorado region. It fed upon certain common weeds, but when the Irish

potato was introduced it transferred its activities from weeds to cultivated potato plants. Since then it has spread all over

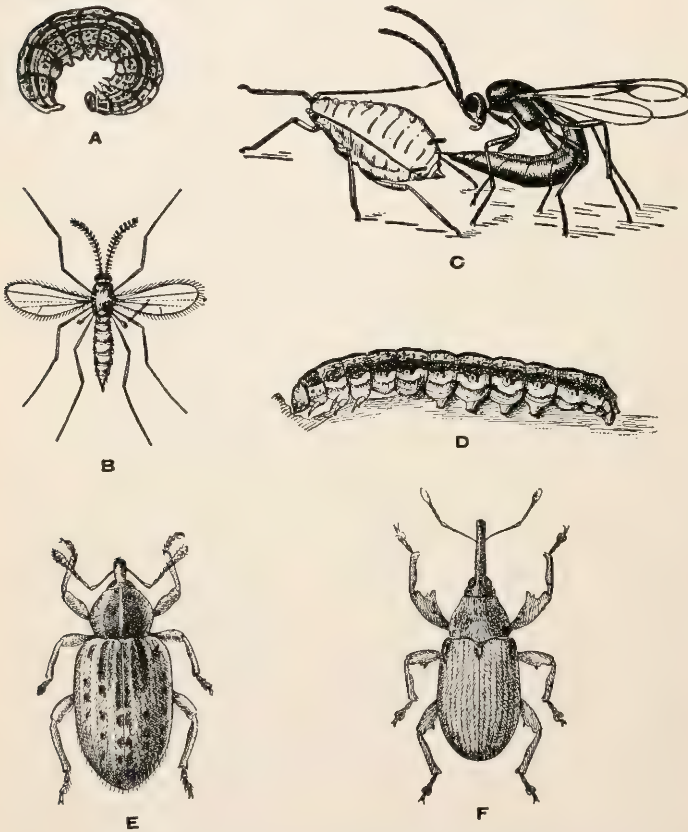

FIG. 18. — Insects injurious to field crops: **A**, cutworm; **B**, Hessian fly; **C**, green bug or aphid (at the left) being parasitized by a minute wasp; **D**, cotton bollworm or corn-ear worm; **E**, alfalfa weevil; **F**, cotton boll weevil. (After various authors.)

this country and has become a pest that must be fought constantly. There are two broods of beetles per year in most parts

of the United States. The yellow eggs are laid in groups of twenty to seventy-five on the undersurface of potato leaves.

FIG. 19. — Potato beetle. Adult and young on plant, and adult enlarged. (Photo by O'Kane.)

The larvæ which hatch from the eggs feed on the leaves until they are full-grown, then they burrow into the ground, change into

pupæ, and finally emerge as adults. Paris green, an arsenical preparation, has proved to be a practical and effective remedy, for when sprinkled on the potato plants this poison is taken into the beetle's stomach with the leaves and quickly kills it.

Cabbage Worm. — The cabbage worm (Fig. 20, C) is the caterpillar of the cabbage butterfly. It is not indigenous to this country but was unintentionally introduced from Europe about 1860, when it first appeared near Quebec, Canada. By 1868 it had reached the Gulf States; since then it has made its way all over the country. The cabbage butterfly (Fig. 20, A) is white with black near the tip of the fore wings, and is about two inches across when the wings are expanded. The larvæ (Fig. 20, C) are velvety green in color and resemble the foliage so closely as to be hardly distinguishable from it. When full-grown they are about one and one fourth inches long. Spraying or dusting with Paris green will kill the larvæ, but some people are afraid to do this for fear of being poisoned when they eat the cabbage. This fear, however, is unfounded, since one would have to eat twenty-eight entire heads at one sitting to feel any poisonous effects from the Paris green. Many cabbage worms are annually destroyed by parasites, one of which, a Braconid fly, is especially

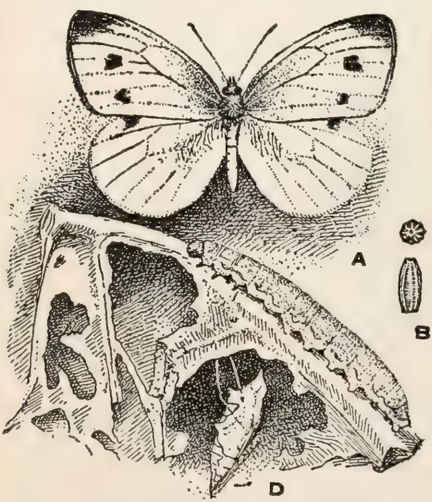

Fig. 20. — Cabbage butterfly: **A**, adult; **B**, eggs; **C**, larva; **D**, pupa or chrysalis.

interesting because it was imported from Europe in 1883 for this very purpose and has "made good."

Other Garden Pests. — Every sort of garden vegetable must struggle against the ravages of its own particular set of insects. Peas and beans are eaten into by the pea weevil (Fig. 21, A) and bean weevil, which cause injuries in this country amounting to several millions of dollars each year; the striped cucumber beetles (Fig. 21, B) attack young cucumber and melon plants; the squash bugs (Fig. 21, C) devour our squash vines; and the celery caterpillar (Fig. 21, D), the larva of one of our most beautiful swallow-tail butterflies, eats the celery leaves before the stalks are ready for the table.

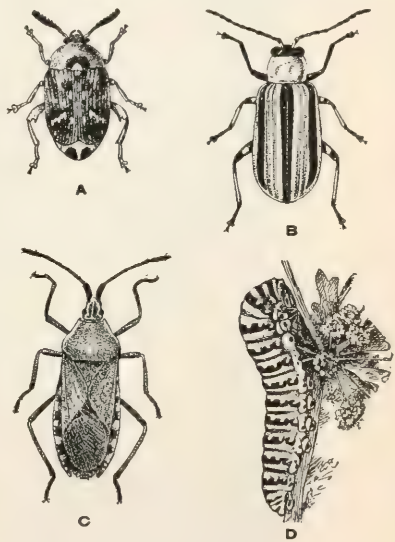

FIG. 21. — Insects injurious to garden vegetables: **A**, pea weevil; **B**, cucumber beetle; **C**, squash bug; **D**, celery caterpillar, the larva of the black swallow-tail butterfly. (After various authors.)

Insects Injuring Fruits. — SAN JOSÉ SCALE. — Perhaps the greatest struggle of all against destructive insects must be made by the horticulturists, for no other vegetation seems so liable to attack as the fruit trees and the fruit they bear. The San José scale insect (Fig. 22) is perhaps the most important of all fruit-tree pests. It appeared in 1880 near San José, California, and from there became distributed over the United States on young trees. The adult female insect is only a fraction of an inch long and lies underneath a small, grayish scale formed by concentric circles and produced by a waxy secretion from the insect. Be-

cause of their small size and protective covering, these scale insects often are not noticed until they become so numerous as to be very destructive. Their powers of reproduction are remarkable; it has been estimated that the progeny of a single

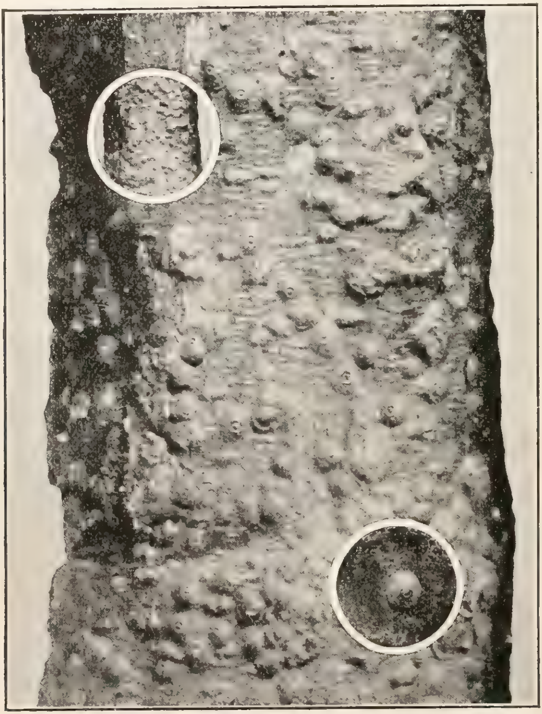

FIG. 22. — San José scales on bark of tree. Small circle above, natural size; small circle below, highly magnified. (Photo by O'Kane.)

female would number over three billion in a single season if all were to survive. Scale insects possess very long, slender piercing mouth parts, which are inserted into the plant to suck out the sap. Not only does the tree become weakened because of the loss of sap, but it is also poisoned by a secretion injected

into it by the scale insect. Two principal methods have been devised to destroy scale insects. One method is to spray the infested plants, during the winter when they are dormant, with a strong solution of lime-sulphur mixture or kerosene oil; the other is to cover the fruit trees one by one with a sort of tent, and generate beneath this hydrocyanic acid gas, which quickly kills the scale insects. Among other scale insects that are injurious to fruit trees may be mentioned the oyster-shell scale and scurfy scale.

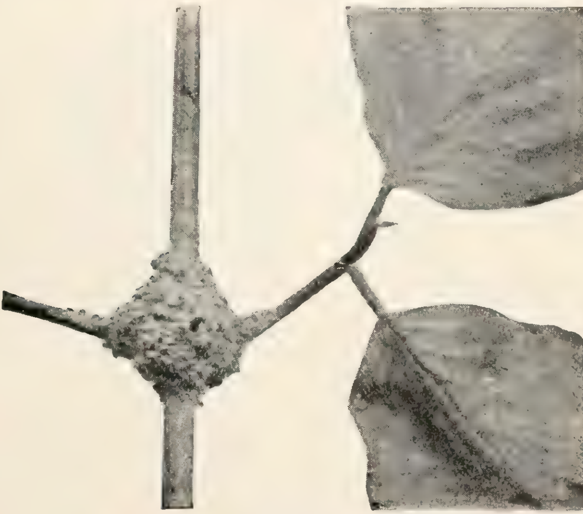

FIG. 23. — A stable made by ants for plant lice or aphids. (From Cornell Leaflet.)

PLANT LICE (Figs. 18, C, and 23). — Closely related to the scale insects is another group of sucking insects, the aphids or plant lice. The woolly apple aphis is a very destructive pest in young apple orchards. It works mostly upon the roots and thus often escapes notice until the trees are badly injured. The common apple aphis of Europe also attacks young apple trees, causing the leaves to curl up and drop off. Associated with the

aphids are always to be found ants which feed upon the drop of "honeydew" secreted by the plant lice. The relations between various kinds of aphids and ants are often very complex. Sometimes the ants cover the aphids with a protecting "shed" of mud (Fig. 23), and it has been shown that the eggs of the corn-root louse are collected by ants in the autumn and stored in their underground nests, where they are cared for until spring when the newly hatched aphids are carried to the roots of the corn. This relationship, termed symbiosis, is mutually beneficial; the aphids are protected by the ants, and the ants are repaid for their trouble with honeydew.

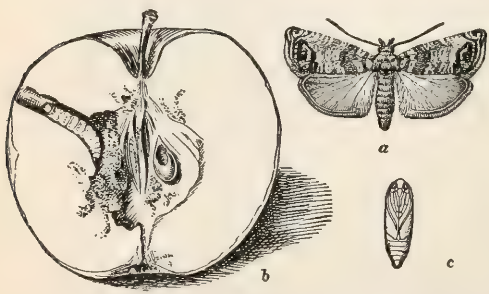

FIG. 24. — Codling moth: **a**, adult; **b**, larva in apple; **c**, pupa or chrysalis. (From Farmers' Bul. 283, U. S. Dept. Agric.)

CODLING MOTH. — There is one fruit enemy with which every one is acquainted, the codling moth, which is responsible for the "wormy" apple (Fig. 24). The eggs of this moth are laid near the apple blossoms, and when the larvæ hatch, they crawl to the nearest young apple, into which they burrow. Most of the injured fruit drops to the ground, and when trees are not sprayed with poisonous mixtures, almost every apple is destroyed. The annual loss in the United States due to this pest is about twelve million dollars.

Insects Injuring Shade Trees. — A problem that has been getting more and more serious within recent years is that of protecting the shade trees of city streets and parks. It is now absolutely necessary for the city forester, or those in charge of parks, to be acquainted with the insect pests that feed upon the leaves of trees and to know how to control them. This is es-

pecially true in New England and other Eastern States, where such injurious insects as the gypsy moth, brown-tail moth, and elm-leaf beetle have recently overrun the country, killing most of the trees in their path. In other parts of the country the tussock-moth caterpillars, leopard-moth caterpillars, and thousands of others are a continual menace to the shade trees, and they must be fought consistently if we do not want our streets to be shorn of their beautiful vegetation.

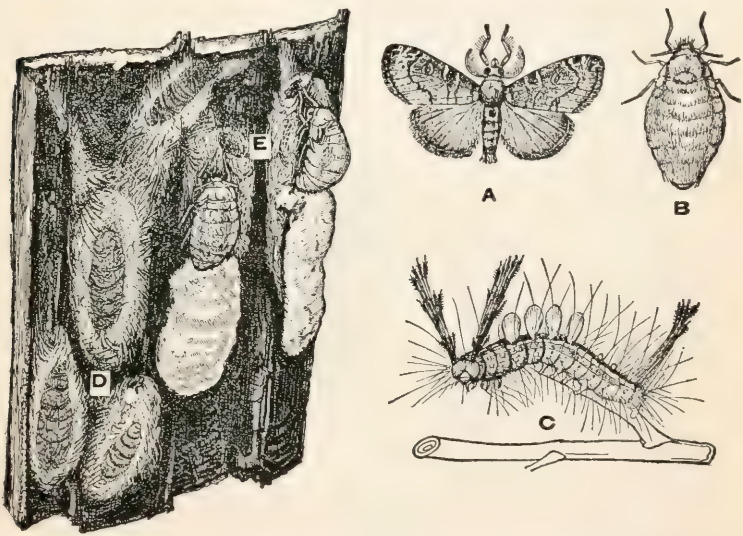

FIG. 25. — The white-marked tussock-moth: **A**, adult male; **B**, adult female (wingless); **C**, caterpillar showing white tussocks on its back; **D**, pupæ in cocoons; **E**, adult females laying eggs on bark of tree.

TUSSOCK MOTH. — The white-spotted tussock moth is very common in various parts of the country. The caterpillar (Fig. 25, C) is a little over an inch long, has a bright red head, and four tufts of white bristles, the "tussocks," on its back. The adult male (Fig. 25, A) is an inconspicuous, dull-colored moth with a white spot near the margin of each wing. The adult female

(Fig. 25, B) has no wings and consequently does very little traveling. She lays her eggs on the cocoon from which she emerges (Fig. 25, E) and covers them with a protective coat of white froth which soon becomes hard and brittle. These egg masses are easily seen on the bark of trees and can be destroyed by painting them with creosote. As a general rule, collecting and destroying the eggs of insects is not a very effective way to control them, but in the case of the tussock moth, potato beetle, and a few others, children can be of immense civic service if they band together to fight these insects in this way. The caterpillars may be poisoned by spraying the infested trees with Paris green, and can be prevented from crawling from one tree to another by banding trees near the base with a sticky substance like tangle-foot.

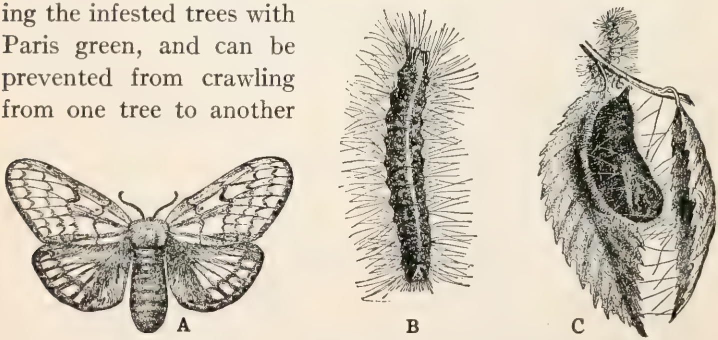

FIG. 26. — Gypsy moth: **A**, female; **B**, larva; **C**, pupa between leaves. (After Howard.)

GYPSY MOTH. — The gypsy moth (Fig. 26) has been extremely injurious to shade trees in certain of the Eastern States. It was introduced from Europe at Medford, Massachusetts, in 1869, but did not become really abundant until about twenty years later. Within the past two decades millions of dollars have been spent in an effort to check the spread of the moths and destroy those specimens already present. The caterpillar (Fig. 26, B) is hairy, and about two inches long. It feeds on all sorts of leaves including pine needles, and does not restrict its diet to one

or a few plants, as do so many other kinds of insects. The adults are brownish and inconspicuous, with a spread of wings of an inch and one half. The female (Fig. 26, A) is too heavy to fly and therefore lays her eggs near where she emerges from her cocoon. Methods of control are therefore similar to those employed for the tussock moth. Many birds feed on the moths

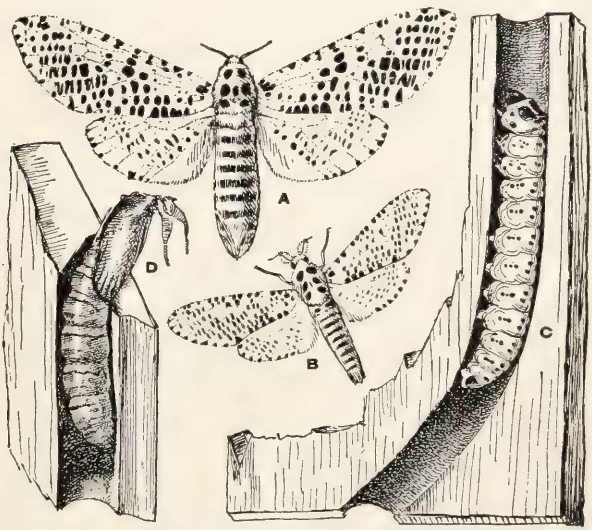

FIG. 27. — The leopard moth: **A**, female; **B**, male; **C**, larva in burrow; **D**, pupal skin from which moth has emerged. (From *Insect Life*.)

and caterpillars, notably the cuckoo, Baltimore oriole, bluejay, and yellow-throated vireo. The United States Bureau of Entomology has been trying for years to introduce predaceous and parasitic insects that will kill off the gypsy moth, but so far has been only partially successful. Perhaps more effective than these is a disease called flasherie which kills off vast numbers of caterpillars each year. It is interesting to note that Pasteur many years ago in France studied a similar disease of the silkworm and was able thereby to save the silk industry of that

country. Incidentally, this study was part of a series of studies which led to a cure for hydrophobia.

Leopard Moth. — The caterpillar of another moth, the leopard moth (Fig. 27), is an important shade-tree pest, but with very different habits from those of the gypsy moth. The leopard moth was also introduced from Europe. Both the adults and larvæ are spotted like a leopard. The male moth (Fig. 27, B) expands a little more than an inch and the female (Fig. 27, A) over two inches. The larvæ, which are about two inches long (Fig. 27, C), burrow into the wood of trees that are weakened by the weather or by some other insect. Serious attacks can be prevented by digging out the boring caterpillars as soon as they appear, or by collecting the adults as they congregate in the evening beneath electric street lights.

Other Shade-tree Pests. — A few of the multitudes of shade-tree insects are the elm-leaf beetle, the elm-bark louse, tent caterpillars, fall webworm, elm, maple, and locust borers, and cottony maple scale. Certain trees are less liable to attack than others. For example, the tulip tree and the hardy catalpa are practically immune from insect injury; oak trees suffer some damage; the Norway maple, white oak, and honey locust, each have one somewhat serious enemy; the linden, horse chestnut, and soft maple have at least one notorious insect pest; and the elm, cottonwood, and black locust are the most seriously injured of all.

Methods of Control. — A great deal can be done to check the spread of shade-tree pests by planting different kinds of trees near each other, rather than massing many of one kind together. Since each insect is usually restricted to one kind of food, the planting of different sorts of trees will prevent the spread of insects from one tree to another. This should always be kept in mind when planting a row of trees. For example, the forest tent caterpillar is a serious enemy of the sugar maple, but not of the soft maple; hence if these trees are placed alternately in a row, wandering tent caterpillars would have difficulty in getting from one sugar maple to another. It takes many years for a tree to reach

the size when it is most valuable, and the importance of preserving the shade trees of our city streets cannot be too strongly emphasized.

It is highly desirable that citizens should band together in the interest of good shade. A most excellent plan was recently urged by one of the Washington newspapers. It advocated a tree protection league, and each issue of the paper through the summer months contained a coupon which recited briefly the desirability of protecting shade trees against the ravages of insects, and enrolled the signer as a member of the league, pledging him to do his best to destroy the injurious insects upon the city shade trees immediately adjoining his residence. This was only one of several ways which might be devised to arouse general interest. The average city householder seldom has more than half a dozen street shade trees in front of his grounds, and it would be a matter of comparatively little expense and trouble for any family to keep these trees in fair condition. It needs only a little intelligent work at the proper time. It means the burning of the webs of the fall webworm in May and June; it means the destruction of the larvæ of the elm-leaf beetle about the bases of the elm trees in late June and July; it means the picking off and destruction of the eggs of the tussock moth and the bags of the bagworm in winter, and equally simple operations for other insects, should they become especially injurious. What a man will do for the shade and ornamental trees in his own garden he should be willing to do for the shade trees ten feet in front of his fence.[1]

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[1] Howard, L. O., Circular 15, Bureau of Entomology, U. S. Department of Agriculture.

CHAPTER V

INSECTS PARASITIC ON DOMESTIC ANIMALS AND MAN

DOMESTICATED animals are those whose ancestors were once wild, but which have been tamed because of their usefulness to man. Insects may affect domestic animals in a number of different ways; first, by occasional attack for the purpose of obtaining food; second, by occasional attacks which simply give irritation to the animal, as in the case of certain species of flies; third, by living as parasites during part of their existence, as in bots; fourth, by living as parasites throughout their lifetime, as with the lice; and, fifth, by living as messmates or scavengers upon the bodies of the animals without deriving nutriment from them, as, probably, some species of bird lice.[1] Practically all of these insects are parasites and are modified in structure and habits because of their parasitic methods of life. Of the hundreds of different kinds of insect parasites the four most important groups are the botflies, fleas, lice, and ticks. Man, as well as the lower animals, is attacked by them.

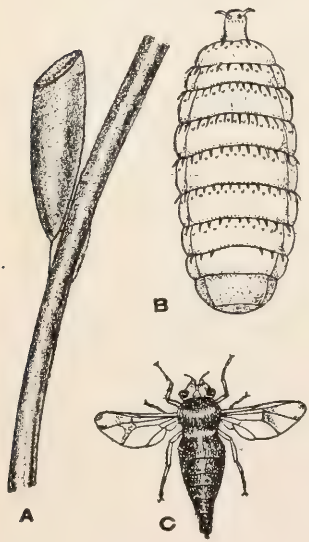

FIG. 28. — Horse botfly: **A**, egg attached to hair; **B**, larva showing spines; **C**, adult female. (After Osborn.)

[1] Osborn, H., *Insects Affecting Domestic Animals.*

Botflies. — The botflies are all heavy-bodied insects resembling small bumblebees. Their mouth parts are very weak, and it is probable that no food is eaten by the adults. The *horse botfly* (Fig. 28, C) is about half an inch long, and brownish

Fig. 29. — Larvæ (bots) of the horse botfly attached to the wall of a horse's stomach. (Photo by Osborn.)

yellow in color. It attaches its yellowish eggs to the hair on the shoulders, legs, or belly of the horse (Fig. 28, A). These eggs are licked off and swallowed by the horse, and the larvæ which hatch from them (Fig. 28, B) fasten themselves by means

of rows of hooklets to the lining of the stomach (Fig. 29). As a result of the presence of several hundred "bots," the horse suffers because of interference with its digestion, and from the irritation caused by the insects. When full-grown, the larvæ pass out of the alimentary canal with the excretions and pupate in the ground. The eggs are plainly visible when attached to the hairs of the animal; the hair should be shaved off or moistened with kerosene, which kills the eggs.

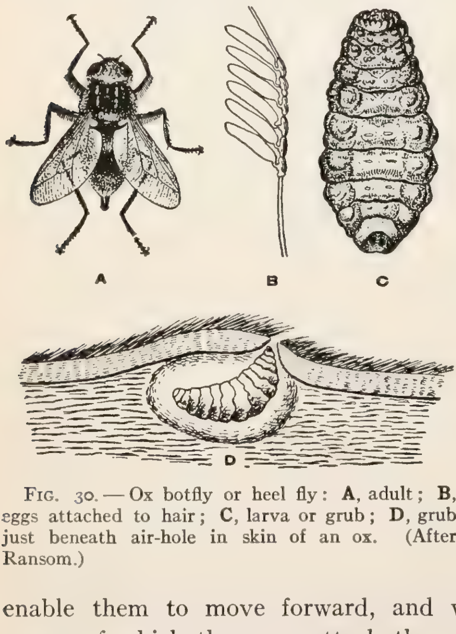

Fig. 30. — Ox botfly or heel fly: **A**, adult; **B**, eggs attached to hair; **C**, larva or grub; **D**, grub just beneath air-hole in skin of an ox. (After Ransom.)

The *sheep botfly* resembles the horse botfly in general appearance but differs from it in its habits. The eggs of the sheep botfly hatch within the body of the fly and the living young are deposited during June and July in the upper nasal passages of the sheep, where they feed upon mucus. They are provided with short, stiff spines which enable them to move forward, and with mouth hooks by means of which they can attach themselves to any place selected. Sometimes these disgusting larvæ even make their way through the skull and into the brain, causing "staggers," a disease that results in death. A mixture of tar and grease smeared on the sheep's nose is partially successful in warding off the attacks of these flies. When the sheep actually become parasitized, the bots may be dislodged by causing the animals to sneeze them out, the sneezing being induced with powdered

lime or by tickling the inside of the nostrils with a feather dipped in turpentine.

The *ox heel fly* has still a different life history. The eggs (Fig. 30, B) are fastened to the hair near the heels of cattle and licked off as are those of the horse botfly. The larvæ (Fig. 30, C) act very differently, however. They bore their way through the walls of the œsophagus and through the body, until after about six or eight months they finally lie just beneath the skin of the back, where they make a breathing hole through the hide (Fig. 30, D). When full-grown, they are about two thirds of an inch long; they then burrow out and drop to the ground, where they complete their life history. The heel fly causes losses of three kinds; first, loss in milk and flesh; second, damage to hides from being punctured; and third, loss in trimming out damaged meat from dressed carcasses. The loss of milk due to these insects may be as high as twenty-five per cent; the loss in flesh is estimated at from one to five dollars per animal; and that to the hide at about sixty-five cents each. The entire annual loss to the sixty million cattle in the United States, of which about fifteen million are infested, is estimated at from fifty-five to one hundred and twenty million dollars. The most successful method of dealing with the bots is to remove them one by one from the backs of the cattle by squeezing them partly through the breathing pores made in the hide and then extracting them with tweezers.

Human beings may under abnormal conditions be attacked by bots. There are a number of cases on record, but they are so rare that no one need be afraid of becoming a victim.

Fleas. — The flea is a degenerate insect with an extremely small head and no wings. Unlike most of its relatives, its body is very narrow and deep instead of broad and flat; this enables it to glide easily among the hairs or feathers of its host. Its legs are adapted for leaping, and the biting mouth parts of the larva are adapted for feeding upon particles of decaying animal and vegetable matter. Fleas are present on a great many kinds

of animals, including the dog, cat, rabbit, pigeon, and poultry, and are often a nuisance to man.

The *jigger flea*, or chigoe (Fig. 31) is a common pest of man in tropical and subtropical countries. When ready to lay eggs, the female burrows into the skin, usually of the feet, causing a swelling which may become a dangerous ulcer. The best way to get rid of this uncomfortable parasite is to prick out the entire

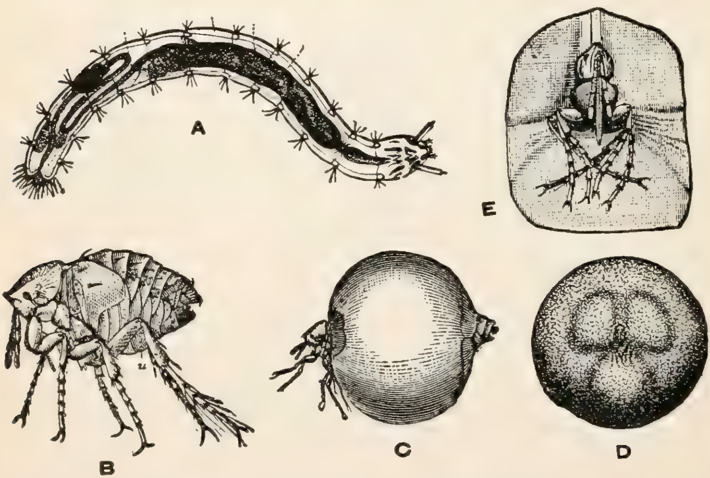

FIG. 31. — The jigger flea or chigoe: **A**, larva; **B**, adult; **C**, side view of adult after a meal; **D**, front view of same; **E**, head and legs much magnified. (After Karsten and Guyon.)

insect, being careful not to break the body so as to free the eggs, as this might lead to serious trouble.

The *cat and dog flea* (Fig. 32) is very common in houses almost all over the world. It is a minute reddish brown insect with a row of black, toothlike spines on each side of the head. The eggs (Fig. 32, B) are laid in the fur of the infested animal, but they are not very firmly attached and when the cat or dog walks about, they are widely scattered. A kitten thus infested is said to have left fully a teaspoonful of eggs upon the dress of a lady in whose

lap it had been held for a short time. The eggs hatch in about ten days; the larvæ are full-grown in twelve days, and the adult emerges two weeks later.

The *house flea* is very much like the cat and dog flea but lacks the spines on the side of the head. House fleas usually conceal themselves in bedding and clothing, venturing out, particularly at night, to feed upon the blood of their victims. Their eggs are laid in dusty crevices or under carpets. The careful removal of dust will decrease their numbers and a thorough dusting of

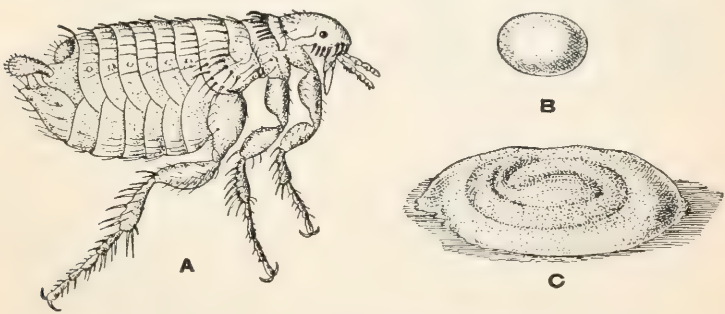

FIG. 32. — Cat and dog flea: **A**, adult; **B**, Egg; **C**, larva in cocoon. (After Howard.)

their breeding places with insect powder (pyrethrum) will destroy them, but no amount of cleanliness will protect a human being who enters an infested building. Recently fleas have become of special world-wide importance because of their relation to the transmission of bubonic plague. (See Chapter X, page 98.)

Ticks. — Many more or less degenerate insects are called "ticks," although this name really belongs to certain small relatives of the spider possessing four pairs of legs. The ticks are parasitic on certain birds, sheep, and horses. Of these the *sheep tick* (Fig. 33) is especially important. This insect is about one fourth of an inch long and spider-like in appearance, with strong sucking mouth parts but no wings. It moves about

readily through wool and sucks the blood from its host. The loss of blood and the irritation caused by ticks hinders the proper development of sheep and when lambs are attacked death often occurs. To destroy ticks, sheep should be dipped after shearing in solutions containing kerosene, tobacco, tar, etc. Such practice not only kills the ticks but it also destroys lice and scab mites if these are present.

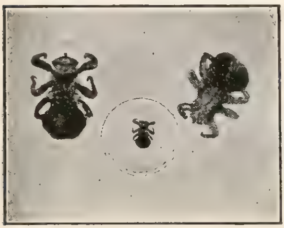

Fig. 33. — Sheep tick. Enlarged and natural size (in small circle). (Photo by O'Kane.)

Lice. — A fourth group of degenerate parasitic insects is made up of the sucking lice. These also are wingless. They possess mouth parts adapted for sucking blood from the poultry, cattle, sheep, and other domestic animals which they parasitize, and also from man. Some kinds of lice have *biting mouth parts* with which they feed on pieces of feathers. The commonest bird louse is the *chicken louse* (Fig. 34, A), a pale yellow insect about one twenty-fifth of an inch long. The eggs or " nits " are fastened to the feathers, and the young, which hatch ten days later, begin at once to feed on the feathers. The irritation caused by the sharp claws of the lice often causes the fowls to dust themselves in the road or a dust box provided for them, thus removing the lice. A mixture of sulphur and lime will help to rid both the poultry house and the poultry themselves of their parasites.

Sucking lice occur on a great many domestic animals, and some, like the ox louse and hog louse, are often very injurious. Those best known are the three that sometimes infest human beings, the *head louse*, *crab louse*, and *body louse* (Fig. 34, B, C, and D). These lice are small, gray or yellowish in color, and elongate oval in shape. They fasten their eggs or " nits " to the hairs of the body and live among them. Lice are, of course, present only on unclean persons, and may be removed easily. They are sometimes very numerous on men crowded together

in camps or prisons. The irritations they produce cause what is known as Pediculosis or Phthiriasis, after the scientific name of the insect. Lice may move from one person to another, so that cleanliness will not always prevent their appearance. The

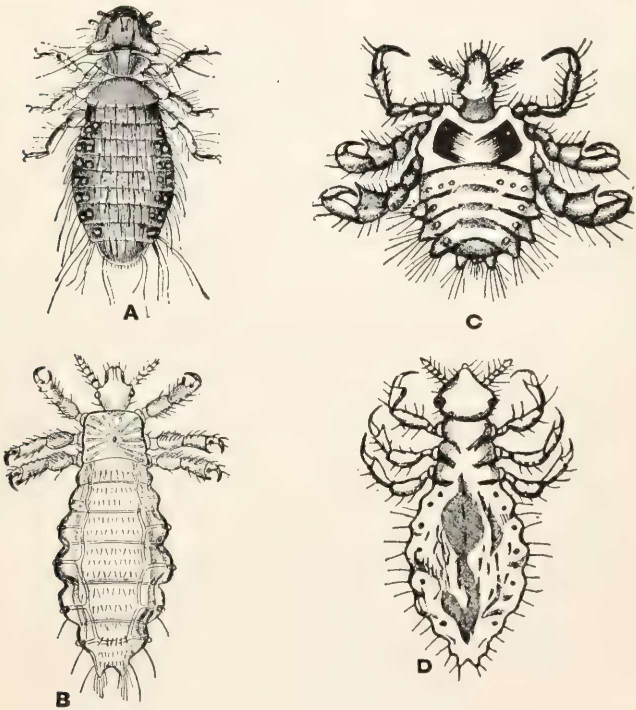

FIG. 34. — Four different kinds of lice.
A, chicken louse; B, head louse; C, crab louse; D, body louse. (After Piaget and Denny.)

best remedies for the head louse are a fine-tooth comb and a thorough greasing of the hair, which chokes the lice. The body lice which infest clothing may be killed by boiling the garments in water, baking them, or dipping in gasoline. Wherever irritations of the skin occur, an application of a mercurial ointment or

of tincture of larkspur should be made. Savages effectually destroy lice by covering their bodies with grease, oil, or paint.

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CHAPTER VI

INSECTS OF THE HOUSEHOLD

Almost every house is invaded at some time during the summer by insects other than the house fly which seems to be always present. Some of these insects, like the house fly, stable fly, mosquito, flea, and bedbug, will be described in Chapters VIII, IX, and X in connection with the transmission of disease germs. The other household insects either simply make themselves a general nuisance, like the cockroach and the silver fish, or contaminate food, as do the ants, meal worm, and cheese skipper, or destroy clothing, rugs, carpets, etc., like the carpet beetle and clothes moth.

Silver Fish. — The silver fish (Fig. 35, A) is one of the simplest of all insects. It has no wings, but is not degenerate, since neither it nor its ancestors ever possessed wings. The silvery appearance of its body, which is due to very small scales, suggested its common name. Starchy substances serve as food material and this is gnawed at night or under cover, since the silver fish always works in the dark. Very little if any damage is done by these insects, but one doesn't like to have the house overrun with them. They may be destroyed by dusting pyrethrum powder in their hiding places.

Cockroaches. — Four different kinds of cockroaches are common in this country, the American cockroach, the Oriental cockroach (Fig. 35, B), the Australian roach, and the German roach or "croton bug." All of them are very flat, soft-bodied insects able to creep into small crevices, and provided with slender legs fitted for running. They work at night and have a preference for kitchens, where they feed on all sorts of scraps, leaving a

disagreeable odor behind them. "Moist articles are preferred, and a warm, wet dishrag which is not washed after using has almost irresistible attractions. If there was only one roach in a kitchen and I wanted that roach, I would place just such a rag on the middle of the floor soon after dark, and I would expect that roach there before ten o'clock. This applies more particularly to the large Oriental roach or 'black beetle,' which is very heavy, does not climb much, and prefers moist places."[1]

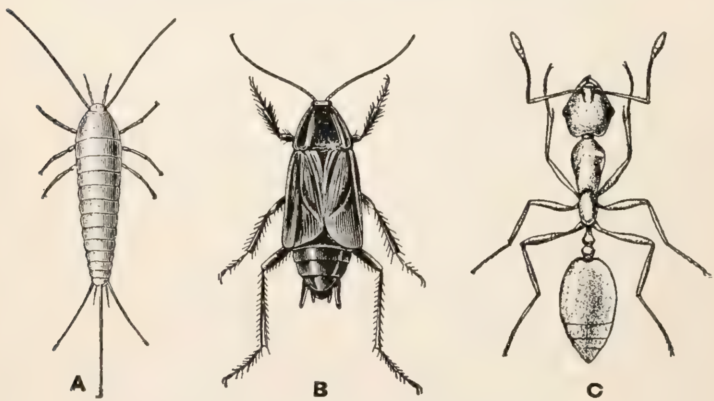

FIG. 35. — Insects of the household.
A, silver fish or fish moth; **B**, cockroach; **C**, red ant. (After Sedgwick and Riley.)

To rid a house of roaches one must use several remedies and persist in their use for some time. Two of those often recommended are (1) a mixture of sugar or chocolate with borax, and (2) plaster of Paris and flour. The sugar or chocolate attracts the roaches and the borax kills them. The plaster of Paris and flour mixture should be placed on a saucer with a saucer of water near by. Eating the mixture makes the roaches thirsty and causes them to drink water; the plaster becomes hardened in their intestines, and death results.

Ants. — Ants often become very troublesome in houses. The

[1] Smith, J. B., *Our Insect Friends and Enemies.*

large black ants are simply visitors from outside that enter occasionally in search of food. The little red ant (Fig. 35, C), however, lives in large nests or colonies in the walls or under the floors. If the nests can be found, they should be destroyed, otherwise the ants must be trapped with pieces of meat or with sponges containing sweetened water; the latter can be dropped into boiling water and then " set " again. Recently an interesting method has been used in California to destroy the Argentine

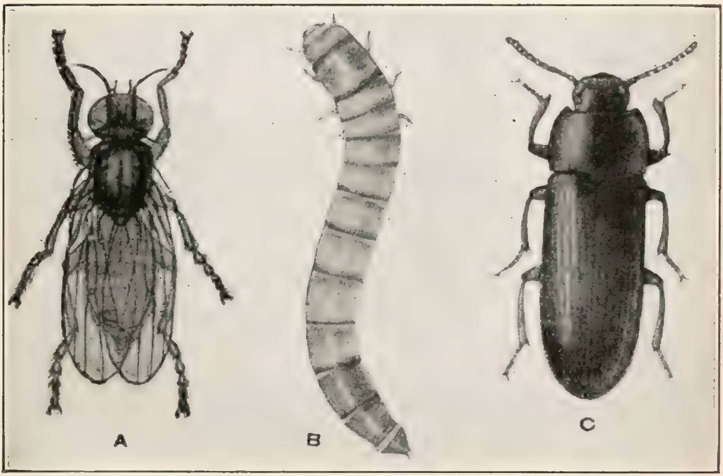

FIG. 36. — Insects of the household.
A, cheese skipper; **B**, meal worm; **C**, beetle into which meal worm develops. (After Chittenden.)

ant. Pans of slow-acting poison were set out. The ants not only fed on this themselves, but carried it to their young, and, as a result, entire colonies were exterminated.

Cheese Skipper. — Articles of food are also rendered unfit to eat by insects which burrow into them. The cheese skipper (Fig. 36, A) breeds in soft cheese and the fatty parts of hams and bacon. The adults are minute, grayish flies, and the larvæ are maggots. Thorough cleaning, followed by fumigation, will destroy these insects.

Meal Worm. — The yellowish or brownish meal worm (Fig. 36, B and C) that sometimes appears in oatmeal and other meals is the larva of a dark, oblong beetle. Heating the meal will kill the eggs, larvæ, and adults.

Carpet Beetles. — Perhaps the most exasperating of all household pests are the carpet beetles or "buffalo moths" and especially the clothes moths. The adult buffalo moth is a dark, white-mottled beetle (Fig. 37, A) about three sixteenths of an inch long. Its larvæ, which are oval, hairy-coated, and about one fourth of an inch long (Fig. 37, B), feed on the wool in carpets,

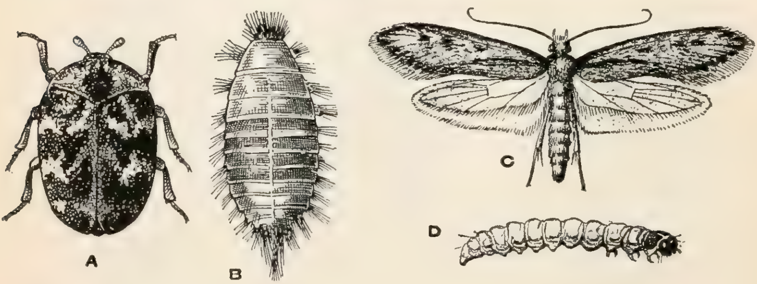

FIG. 37. — Insects of the household.
A, carpet beetle; **B**, larva of carpet beetle; **C**, clothes moth; **D**, larva of clothes moth. (After Riley.)

usually working underneath and following a crack in the floor. When an attack has been discovered, the carpet should be taken up and sprayed with gasoline, and the cracks of the floor should be scrubbed with hot suds and then treated with gasoline.

Clothes Moth. — Clothes moths (Fig. 37, C) are small grayish insects that lay their eggs in woolens or furs. The larvæ (Fig. 37, D) which eat these animal textiles are to be feared only in the summer in the North, but they are busy throughout the year in the South. A few precautions will prevent serious injury. Winter clothes laid away over summer should be taken out occasionally, hung in the sunlight, and thoroughly beaten or brushed to free them from the intruders. Moth balls help keep

out the moths, and clothing tightly sealed in boxes or paper bags will not be attacked.

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CHAPTER VII

BENEFICIAL INSECTS

So much has been written about injurious insects that it seems as though none are of value to man. This is not at all true, since many insects pollinize flowers, others act as scavengers, and a few produce lac, cochineal, tannic acid, medicines, and even food for human beings. Besides these the silkworm and honey-bee have become almost indispensable because of the silk, honey, and wax they furnish.

FIG. 38. — Silkworm: **A**, caterpillar; **B**, cocoon; **C**, adult female moth. (From Shipley and MacBride.)

Silkworm. — The silkworm (Fig. 38, A) is really a domesticated animal, just as much as the horse, dog, or cat. It is the caterpillar of a moth and has a life history as follows: The female moth (Fig. 38, C) lays about three hundred eggs on pieces of cloth or paper provided for it. When the caterpillars hatch, they begin to feed at once on leaves of the mulberry, osage orange, or lettuce. At the end of about six weeks they begin to spin their cocoons (Fig. 38, B). The fluid which forms the silk is produced in the silk glands of the caterpillars; it passes out through the spinneret and hardens on coming into contact with the air. The caterpillars first attach the thread to near-by

objects and then form an oval structure about themselves by winding round and round a single thread a thousand feet in length or thereabouts. The adult moth develops within this cocoon and emerges in about two weeks if undisturbed. To get the silk, however, it is necessary to kill the animal within the cocoon, since if this is not done, the moth destroys one end of it when it comes out. After killing the animal quickly in boiling water or by dry heat, the loose silk is cleared away, the end of the thread found and unwound. Over one hundred million dollars are invested in silk industries in this country.

FIG. 39. — Honeybees.
A, worker; **B**, queen; **C**, drone. (After Phillips.)

Honeybee. — The honeybee is also a domesticated animal, but it even now often returns to its former wild state, making its home in a hollow "beetree." The number of bees in a prosperous hive is about sixty thousand. Most of these are sexually undeveloped females, called workers (Fig. 39, A); a few are males or drones (C), and one is the queen (B). The queen lays all the eggs, the drones fertilize the eggs, and the workers carry on all the activities of the hive. The wax out of which the honeycomb is built is secreted by the glands on the undersurface of the abdomen of the workers (Fig. 40, A). The wax cells

are used for rearing the young and storing honey. Honey is not collected from flowers, but is manufactured from the nectar of flowers. Worker bees lap up the nectar with their tongues and suck it into a honey sac within the body, where it is stored until they return to the hive. Then the nectar is disgorged into the wax cells and left until all but eighteen to twenty per cent of the water contained in it has evaporated. The cell is then sealed with a cap of wax. The flavor of honey depends upon the kind of flowers visited by the bees. In a single season a hive of bees will produce about thirty pounds of comb honey, which nets the bee keeper from ten to fifteen cents per pound.

FIG. 40. — Worker honeybees.
A, removing wax scale; **B**, carrying pollen. (After Casteel.)

Among the other duties of the worker bees, besides those of building honeycomb and manufacturing honey, are the cleaning of the hive, ventilating the hive, guarding the hive, carrying water to the hive for the young in warm weather, feeding the young, and gathering pollen (Fig. 40, B). Pollen grains are the very small fertilizing elements in flowers. Pollen is gathered by the legs of the workers (p. 27, Fig. 12), stored in wax cells, and furnishes the principal food of the larvæ. Bees swarm in early summer, when the hive is in danger of overcrowding. The workers rear a second queen when the hive becomes crowded, and the old queen then leaves the hive with a few thousand workers and founds a new colony.

Cochineal, Lac, etc. — Of less value to man than the products of the silkworm and the honeybee are cochineal, lac, tannic acid, and medicines. The coloring matter known as cochineal is made from a scalelike insect that lives on cactus plants in Mexico and Central America. Lac is derived also from scale insects which

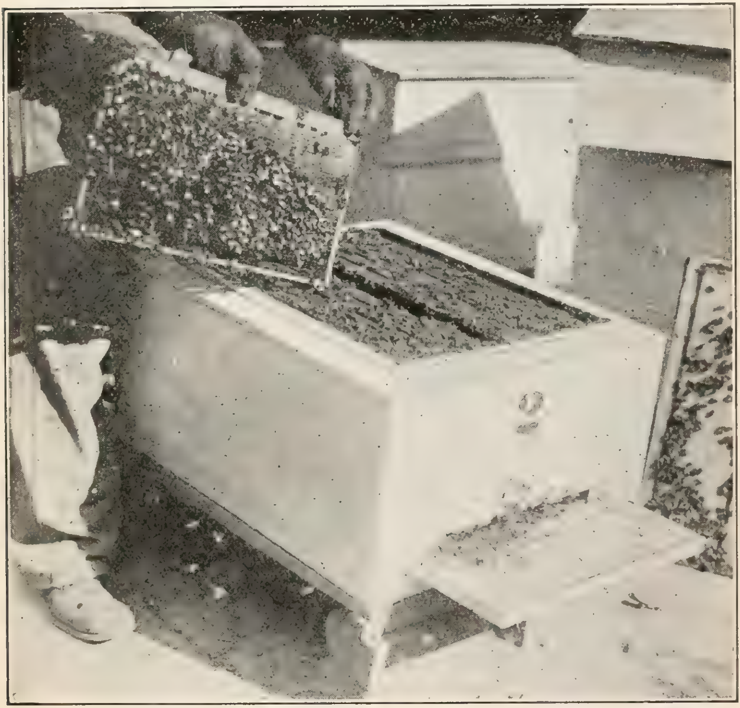

FIG. 41. — A modern beehive. (Photo by Hegner.)

occur principally in the Orient. It forms the base of many fine polishes and lacquers of India, China, and Japan. Part of the tannic acid used in the manufacture of leather is extracted from the swellings on certain plants, called galls (Fig. 42), which are caused by insects. The black coloring matter in some kinds

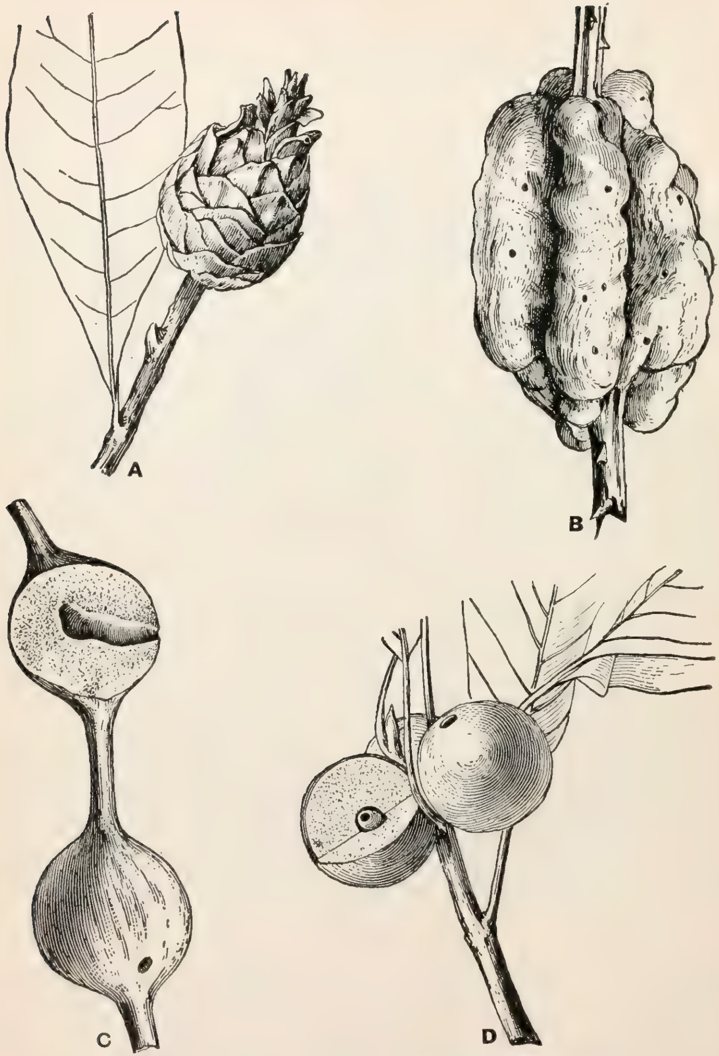

FIG. 42. — Types of insect galls.

A, willow cone gall; B. blackberry knot gall; C, goldenrod gall; D, oak gall. (From Beutenmuller.)

of inks comes from insect-made galls. While formerly many insects were used as ingredients in medicaments, now only a few are thus employed. Of these the blister beetles are the most important, especially the Spanish fly, which is collected in vast numbers, dried, and powdered; it has the property of producing blisters when applied to the human skin.

Food for Man. — Although it is of very little importance, it is interesting to note that certain insects have at various times and in various places been used as food by man. Grasshoppers are eaten by the savages in many countries; when fried, they "are said to have a sweet flavor, while in a stew with milk they recall oysters." The eggs of a water bug are in some localities in South America gathered, dried, and baked into a cake by the natives, and in tropical countries young ants often serve as food for uncivilized mankind.

Scavengers. — The benefits derived from insects which act as scavengers are very little appreciated. To determine their effectiveness one has only to place a small dead animal in a field. Flies find the carrion almost immediately, lay their eggs on it, and the maggots which soon hatch from these eggs immediately begin to devour it. The great Swedish naturalist, Linnæus, once said that a fly could devour the carcass of a horse more quickly than could a lion. The burying beetles also attack dead bodies, digging out the earth from underneath and slowly burying them in the ground.

Other insects feed upon dead and decaying vegetable matter, reducing such obnoxious substances as the excrement of horses and cattle to harmless material that soon becomes mixed with the soil. In fact " if all the insect scavengers were removed at one time and all dead animal and vegetable material left to other decays, the foulness and noxious odors that would be thus let loose are beyond all description."

The most interesting of all the scavenger insects are the " tumblebugs " (Fig. 43). The young of these beetles live in animal excrement and the adults are often found in the fields

rolling large balls of dung to some burying place for the purpose of laying their eggs in it and thus storing up a food supply for their offspring. One of these dung beetles is the Sacred Scarabæus which was held in high veneration by the ancient Egyptians and was used as a model for gems, was painted on sarcophagi, and carved in stone.

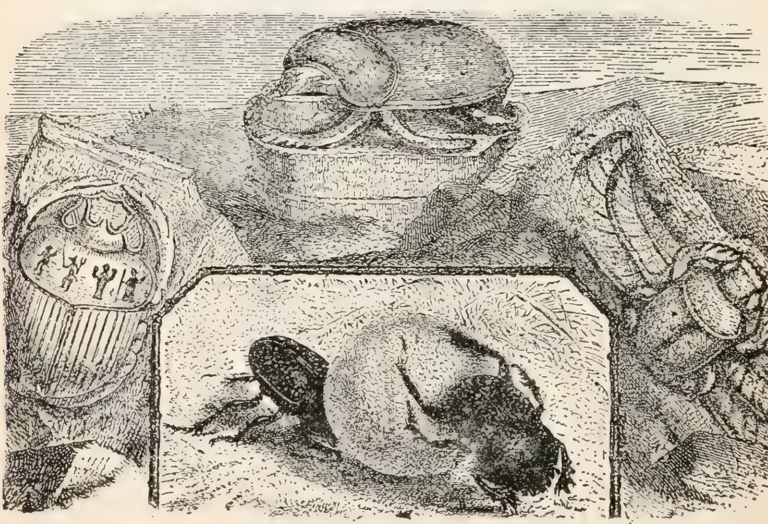

Fig. 43. — Scarab beetles, or tumblebugs, rolling an egg-ball of dung. Egyptian sculptures of sacred scarab. (After Brehm.)

Pollinization of Flowers. — Another indirect benefit derived by man from insects is the result of the relation between bees, wasps, etc., and flowers. Before seeds can be produced, the pollen grains which are borne by the stamens of the flower (Fig. 44, B, *sta*) must become attached to the style (*s*) of the same kind of flower, where it fertilizes the ovule (*o*) from which the seed develops. It has been found by experiments that when the pollen from one flower fertilizes the ovules of another flower (a process known as cross-pollination), better seed and more seed

is formed than when the pollen of a flower fertilizes the ovules of the same flower (self-pollination). Many plants are cross-

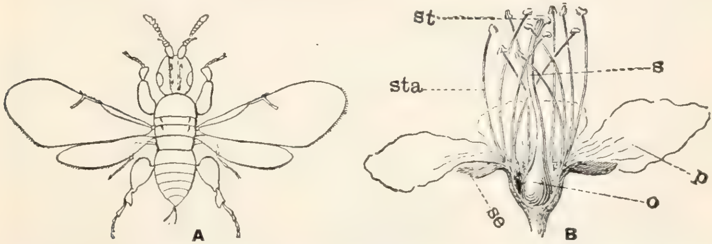

FIG. 44. — **A**, fig insect whose introduction has made Smyrna fig culture possible in California. (After Westwood.)
B, plum blossom; *o*, ovary; *p*, petal; *se*, sepal; *sta*, stamen; *st*, stigma; *s*, style. (After Bailey.)

pollinated only by insects and would not produce good seed if insects did not fly from one flower to another and thus distribute the pollen grains that become attached to their bodies. In some cases the insects seem to realize what they are doing, since they deliberately transfer pollen from the stamen to the pistil. The plants are benefited directly by the production of better seed, and man indirectly with larger and better crops. In return, the insects take nectar from the flowers as their transportation charges.

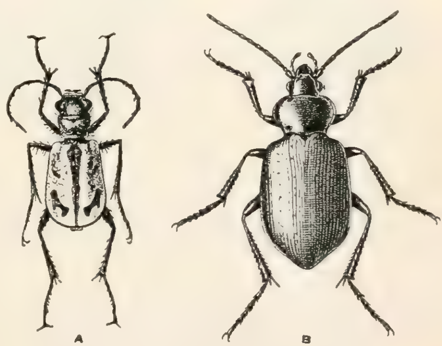

FIG. 45. — Predaceous insects.
A, tiger beetle; **B**, European ground beetle imported to prey upon the gypsy and brown-tail moths. (After Bruner and Howard.)

The dependence of plants upon insects is well illustrated by the Smyrna fig. Prior to the year 1900 this fig could not be

grown in the orchards of California, but since then the causes have been found, and the remedy applied with satisfactory results. The figs did not ripen because their flowers were not pollinized. When pollination was found to be accomplished by a minute insect (Fig. 44, A), this insect was introduced into the fig-growing districts of California and a successful new industry established.

Predaceous Insects. — Beneficial from another standpoint are predaceous and parasitic insects. A predaceous animal is one that feeds directly upon another. Most insects feed on vegetation, that is, are herbivorous, but a goodly number devour animal matter and are carnivorous (Fig. 45). The latter perhaps in the majority of cases, feed upon other insects, and since as a general rule insects are injurious, it is safe to conclude that predaceous insects are beneficial, although they may occasionally destroy useful animals.

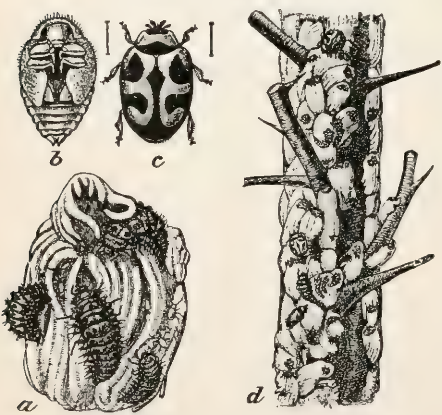

FIG. 46. — Australian ladybird beetle and fluted scale.

a, larvæ of beetle feeding on scale; *b*, pupa of beetle; *c*, adult beetle; *d*, orange twig showing scales and beetles. (After Marlott.)

Rivaling in interest the establishment of the fig industry in California is that of the salvation of the orange and lemon trees of the same region. Kellogg gives the facts in this case in the following words: "In 1868 some young orange trees were brought to Menlo Park (near San Francisco) from Australia. These trees were undoubtedly infested by the fluted scale (Fig. 46), which is a native of Australia. These scale immigrants

throve in the balmy California climate, and particularly well probably because they had left all their native enemies far behind. By 1880 they had spread to the great orange-growing districts of southern California, five hundred miles away, and in the next ten years caused enormous loss to the growers. In 1888 the entomologist Koebele, recommended by the government division of entomology, was sent at the expense of the California fruit growers to Australia to try to find out and send back some effective predaceous or parasitic enemy of the pest.

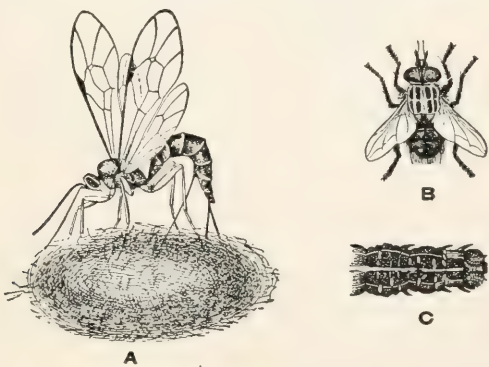

FIG. 47. — Parasitic Insects.

A, parasitic Ichneumon fly laying eggs in the cocoon of a tent caterpillar; B, parasitic tachina fly; C, part of an army worm with tachina fly eggs attached to it. (After Fiske.)

As a result of this effort, a few Vedalias (Fig. 46) were sent to California, where they were zealously fed and cared for, and soon, after a few generations, enough of the little beetles were on hand to warrant trying to colonize them in the attacked orange groves. With astonishing and gratifying success the Vedalia in a very few years had so naturally increased and spread that the ruthless scale was definitely checked in its destruction, and from that time to this has been able to do only occasionally and in limited localities any injury at all."

Parasitic Insects. — Parasitic insects (Fig. 47) are those that

live in or are carried about on the bodies of other animals. Some of them are harmful, such as lice, but others are beneficial because they parasitize and kill other injurious insects. As a rule the parasites are very small. They lay one or more eggs in or upon the body of their victim, the host, and the young insect that soon emerges from the egg feeds slowly upon the substance within the host's body. It finally reaches the adult stage and leaving the remains of its victim behind, escapes in search of new prey. At the present time many insect pests, such as the army worm, tussock moth, and gypsy moth, are partially held in check by parasites, and the Bureau of Entomology of the Department of Agriculture is making all possible efforts to introduce into this country parasites from foreign lands in the hope of finding some that will equal the performances of the predaceous Vedalia lady beetle.

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CHAPTER VIII

THE HOUSE FLY AND DISEASE

No animal has been subjected to a more careful study within recent years than the house fly. The reason for this is that the house fly distributes the germs of various diseases, thus causing the death of thousands of human beings every year. As we shall see later (Chaps. IX and X), the house fly is not the only guilty insect, but its abundance makes it especially important.

Disease Germs. — The disease germs that are carried by flies and other insects must be described before it is possible to discuss properly their method of transmission. These germs are either plants called *Bacteria* or animals called *Protozoa*. (See Chapter XXV.) In either case they are exceedingly small, so minute in fact that many of them can only be seen with the highest magnifications of the compound microscope and some, like the yellow-fever germ, have never been seen.

Bacteria. — The bacteria (Fig. 48) are of various shapes and sizes, being as a rule spheres (micrococci), straight rods (bacilli), or bent rods (spirilla). They range in size from $\frac{1}{25000}$ to about $\frac{1}{1000}$ of an inch in length. Some bacteria are able to move, but many must be carried from place to place. Bacteria increase in number by reproduction, just as do the grasshopper and other living things. The body of the bacterium divides in the middle into two, a process known as binary fission. Then each part grows rapidly and divides again. In some cases bacteria become full-grown and divide every half hour. How many offspring would be produced in twenty-four hours by such a bacterium

can be estimated by any one who is mathematically inclined. Bacteria, like other living things, must have food (which consists of mineral matter and plant or animal substances), moisture, and usually free oxygen. Fortunately, only a few bacteria cause diseases; these are called *pathogenic*. The others, or *nonpathogenic bacteria*, act as scavengers in the earth, furnish food for plants, and are used in various industries, such as in the manufacture of linen and cheese. Bacteria are almost everywhere; they are in every breath of air we breathe, in most of the water we drink, and are abundant in the earth.

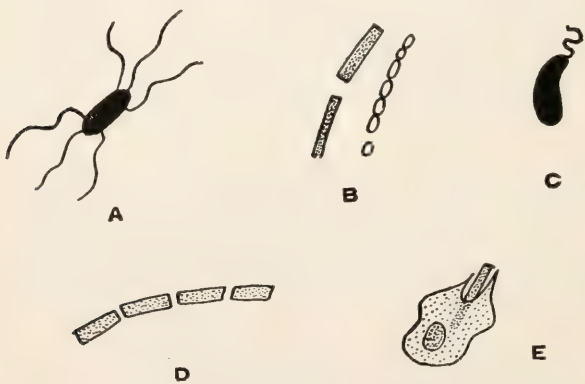

FIG. 48. — Disease germs — bacteria.
A, typhoid; **B**, tuberculosis; **C**, cholera; **D**, anthrax; **E**, a blood corpuscle engulfing a germ.

HOW TO DESTROY BACTERIA. — It is necessary to know how to destroy or prevent the increase of bacteria in order to protect ourselves from the pathogenic kinds. Cleanliness will of course dispose of most of those that rest upon the surfaces of our bodies. Within the body, juices and white blood corpuscles are continually at work destroying many of those that manage to get in. Various agents are employed for controlling bacteria. Substances called antiseptics prevent their growth; disinfectants or germicides kill pathogenic forms; and all kinds are killed by

sterilization. We base our methods of control upon our knowledge of the agents harmful to bacteria. Sunlight is their greatest destroyer, whereas they grow best in the dark. Heat stops their multiplication at 109.4° F., and cold at 60.8° F. Many of them are killed at 32° F., but unfortunately the bacteria causing typhoid fever and Asiatic cholera are not, and hence may be dis-

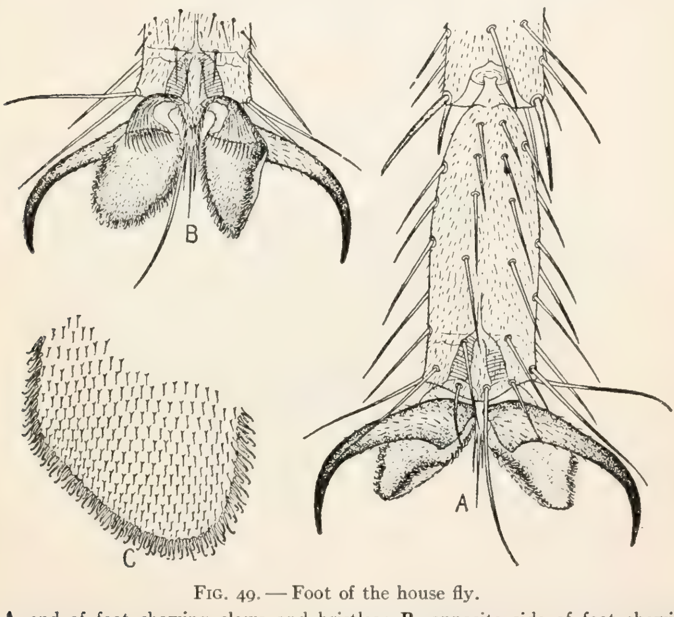

FIG. 49. — Foot of the house fly.

A, end of foot showing claws and bristles; **B**, opposite side of foot showing fleshy lobes, the pulvillus; **C**, part of pulvillus much enlarged showing hooked hairs. (After Smith.)

tributed in ice. It is evident that the cooling of foods, such as milk, will prevent the multiplication of germs and hence keep them from spoiling, and that surgeons' instruments may be rendered aseptic, that is, free from bacteria, by heating or boiling. Gases, such as formaldehyde, and liquids, such as bichloride of mercury and carbolic acid, are commonly used as disinfectants.

HOW GERMS ARE CARRIED. — The house fly is important because it carries on its body or in its alimentary canal many of the pathogenic bacteria. Flies very easily become soiled with particles of filth in which millions of bacteria live, and this filth is transferred to any object upon which they alight. Most of the germs are carried upon the *legs*, or are taken into the alimentary canal and vomited or deposited as excreta. That the legs are very easily soiled is due to the presence upon them of numerous hairs among which the germs become lodged (Fig. 49). Hairs

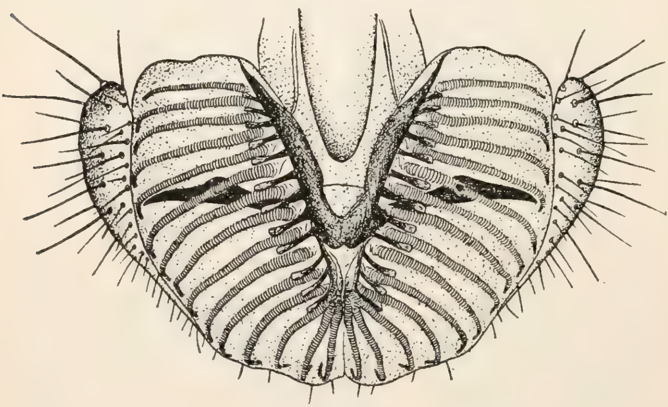

FIG. 50. — The lapping organ at the tip of the proboscis of the house fly. (After Smith.)

on other parts of the body may likewise catch groups of bacteria. The number of bacteria on a single fly has been found to average about 1,250,000.

The *mouth parts* of the house fly also aid in the distribution of germs. They are modified for lapping and form a sort of proboscis. This is a fleshy organ about as long as the head, with two lobes at the top covered with very fine ridges (Fig. 50). Within the proboscis is a tube leading to the stomach. Solid food, such as sugar, must be liquefied before it can be swallowed. The fly does this by pouring out upon it a little saliva and then

rasping it with the lobes of the proboscis. If the fly chances to feed on substances containing bacteria, these are taken into the alimentary canal and later may be extruded through the mouth, or deposited in the excreta which forms " fly specks." The conclusion is evident: a fly that has access to substances containing bacteria cannot help but become soiled by them and later transfer them to other objects, such as articles of food (Fig. 51 *a*).

FIG. 51 *a*. — Plate of gelatine, showing colonies of bacteria in footprints of a house fly. (After Underwood.)

Germ Diseases Transmitted by House Flies. — After having shown that the house fly carries bacteria, we must inquire as to what sorts of diseases may be caused by these bacteria. Lack of space makes it impossible to give the evidence upon which our statement is made, but there is convincing proof that the germs of typhoid fever, Asiatic cholera, summer diarrhœa, tuberculosis, yaws, ophthalmia, smallpox, and tropical sore are carried by flies. The relation between flies and typhoid fever is well

known and so important that the house fly is now often spoken of as the *typhoid fly*.

Typhoid Fever. — The typhoid fever germ is a bacillus (*Bacillus typhosus*) about $\frac{1}{10000}$ of an inch long (Fig. 48, A). It occurs principally in the intestine, lungs, blood, and bladder of man, and is taken into the alimentary canal with water, ice, milk, and other foods. Typhoid bacilli are discharged from the body in the excretory matter and in sputum. It is therefore very important that all excretory matter from typhoid fever patients be screened from flies or treated so as to kill the germs. In certain cases the patient may have, to all appearances, completely recovered and yet continue excreting the typhoid bacilli. These cases are known as "carriers" and the number of such "carrier" cases who continue to carry the typhoid germs in their bodies is gradually increasing as the matter is being more carefully investigated. It is being discovered that many of the inexplicable outbreaks of typhoid fever are due to the presence of one of the chronic carriers. The presence of an unrecognized "carrier" excreting infected matter, the occurrence of large numbers of flies, and their access to food or milk are all the factors that are required to initiate an epidemic of typhoid fever, and not a few epidemics are now being traced to the concurrence of these factors.[1]

Dysentery. — Similar in some respects to the typhoid bacillus is the bacterium that causes summer diarrhœa or dysentery in children. The germ (*Bacillus dysenteriæ*) resembles that of typhoid in size and shape, and is taken into the system with water and foods in the same way. The bacilli are especially active in the intestines, where they cause serious disturbances, often resulting fatally. It has been shown quite clearly that the number of cases of summer diarrhœa corresponds very closely to the number and activity of house flies. During wet seasons, which are unfavorable for the multiplication of flies, the number of cases of dysentery is much smaller than during dry seasons.

[1] Hewitt, C. G., *House-Flies and how they spread Disease.*

Tuberculosis. — It has been known for many years that flies carry the bacillus of tuberculosis (Fig. 48, B), and everything seems to point to the conclusion that the disease is at least to some extent spread by them. Flies are attracted by sputum, and when they chance to alight on that of tuberculous persons, they take the bacilli into their intestines. Here the germs may remain for days, during which the flies distribute them in their excreta. The chief danger is from carelessness in the disposal of sputum from tuberculous patients, since flies may easily carry the germs to food. Some idea of the losses from tuberculosis in this country may be judged from the following statistics.[1]

In 1906, 138,000 persons died from tuberculosis in the United States, or at the rate of 164 per 100,000 population. Based upon these facts, it is estimated that about 5,000,000 of those now living in the United States will die of the disease. It is claimed that the disease alone costs the United States from $400,000,000 to $1,000,000,000 each year (Fisher).

It is estimated by the United States Bureau of Animal Industry that 2 per cent of hogs in the United States are tubercular, and that losses of stock in the United States, due to tuberculosis, amount to $23,000,000 annually. Of 400,000 cattle tested in the United States 9.25 per cent were tubercular.

Asiatic Cholera. — Asiatic cholera is a disease common in India, from which place it frequently spreads throughout the world. Several epidemics have occurred in America, and New Orleans and other seaports are often threatened. The germ that causes cholera is a spirillum bent in the form of a comma (Fig. 48, C.) It gains entrance to the human body in food or drink and lodges in the intestines. The method of spreading cholera germs is therefore very similar to that of the typhoid bacilli. The house fly is an important carrier and preventive measures should be taken accordingly.

Other Diseases. — Not so much is known about the other diseases that may be caused by germs distributed by flies. Cer-

[1] Marshall, C. E., *Microbiology*.

tain tropical diseases are doubtless transmitted by insects. Yaws, a disease caused by a spiral parasite, is probably carried by house flies which infest the victims. The possibilities of spreading the infection are obvious.

Another tropical disease, *opthalmia*, characterized by inflamed eyes, is no doubt carried by flies, since hosts of these insects swarm about the eyes of infected individuals.

Besides the germ diseases mentioned above, house flies probably distribute certain *parasitic worms* that occur in the intestines of human beings. The eggs of such animals as the tapeworm are very minute and are known to be sucked up by house flies. These eggs may then be deposited by the fly upon the food of man, and young tapeworms may be hatched and liberated in the human stomach or intestines. The eggs of worms may also be carried on the legs or proboscis of the flies.

Methods of Control. — To control the infectious diseases spread by house flies it is necessary to prevent so far as possible the multiplication of the insects and also to prevent those flies that cannot be destroyed from distributing the germs. The destruction of the flies is the best way to attack the problem, but before we can do this intelligently we must know the life history of the insect.

Breeding Habits of House Flies. — The eggs of house flies are laid principally in horse manure, but may also be deposited in the excreta of other animals, in decaying vegetables, fruit, and grain, and in various kinds of garbage. The flies begin to breed in June and continue to multiply until October. One fly deposits about five hundred eggs, each about $\frac{1}{25}$ of an inch long. Within twenty-four hours the eggs hatch and the maggots that emerge (Fig. 51 *b*, A) begin to feed upon the liquids surrounding them. It takes the larva about five days to become full-grown; then it pupates (Fig. 51 *b*, B). About four days later the adult fly emerges from the pupal covering (Fig. 51 *b*, C). These adults are ready to lay eggs in about two weeks, so that the life cycle from egg to egg lasts a little over three weeks. During the summer,

manure piles contain an enormous number of maggots; an average of fifteen hundred to every pound of manure has been recorded.

Enemies of House Flies. — In the late autumn there is a notable decrease in the number of flies and in winter none are present except in warm situations. The question has often been asked, What becomes of the flies in the winter, and where do the flies come from in the spring? House flies, like all other animals, have many enemies. Numerous birds, such as vireos and phœbes, are known to catch them; predaceous insects, like

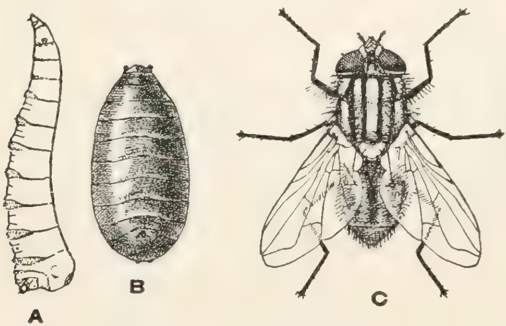

FIG. 51 *b*. — The house fly.

A, larva or maggot; **B**, puparium; **C**, adult. (After Howard.)

the wasps, destroy many of them; toads, frogs, and lizards devour them whenever they get a chance; and the house centipede (Fig. 52, A) is a constant enemy. These animals are all attacking the flies during the summer. As autumn approaches a fungous plant (*Empusa muscæ*) kills enormous numbers of them; it is, in fact, their worst enemy. This plant is responsible for the death of the flies that are often found attached to window-panes and surrounded by a grayish ring which consists of the seedlike reproductive bodies of the plant (Fig. 52, B). A large proportion of the flies die a natural death, but the vigorous young crawl into crevices, where they pass the winter in a quies-

cent state. Like the woodchucks, certain bears, frogs, etc., they hibernate during the cold, unfavorable months.

Prevention of Breeding. — The best means of decreasing the number of house flies is undoubtedly to prevent them from breeding. This means that the materials in which flies lay their eggs and develop should be protected from them in some way. Horse manure is the principal breeding material. Either fly-proof receptacles or chambers should be provided for manure, or the manure, when accessible to flies, should be treated with some substance which kills the maggots. A small amount of chloride of lime thrown over the manure will do this, or an application of iron sulphate solution, in the proportion two pounds of iron sulphate to one gallon of

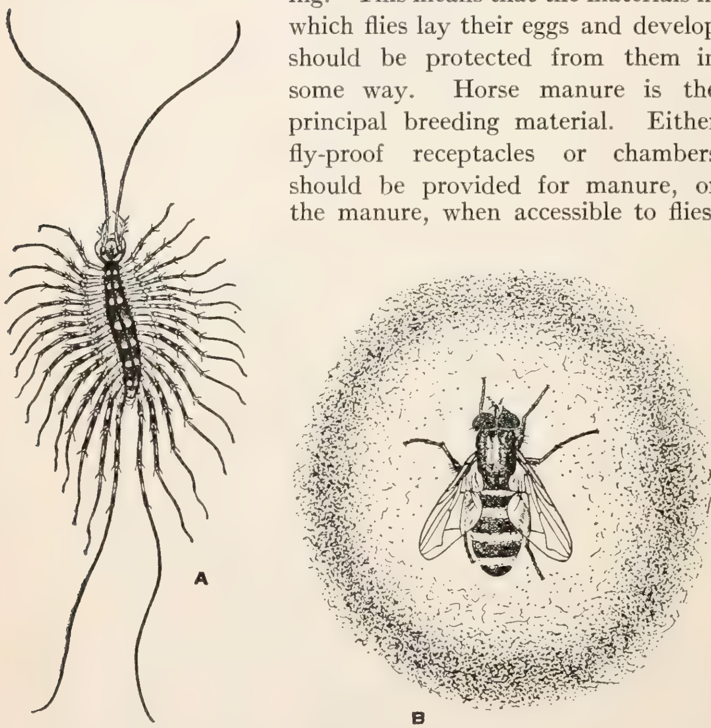

FIG. 52. — Enemies of the house fly.
A, centipede; **B**, dead fly surrounded by spores from a fungous plant which has killed it. (After Folsom.)

water. These do not interfere much with the manurial properties of the manure, and the horses will be more fit for work if their stable is not infested with flies.

A second breeding place that needs attention is the old-fashioned insanitary privy, where germs are gathered by flies and then distributed over our food, and on the faces and feeding bottles of infants. Wherever extra sanitary precautions have been taken, a decrease in the death rate of infants due to intestinal diseases has always resulted. Local authorities thus have a serious responsibility in enforcing sanitary measures.

The third common breeding place of the house fly is in all sorts of refuse, such as in unprotected garbage cans, city dumps, etc.

It is possible to diminish the number of flies by catching the adults in flytraps or with sticky fly paper, or by poisoning them. An excellent method of killing flies is with a solution of two tablespoonfuls of formalin in a mixture of one half a pint of sweet milk and one-half a pint of water. This should be exposed in shallow dishes with a piece of bread in the center on which the flies may alight.

Prevention of Distribution of Germs. — The best means of preventing the transference of germs are, first, the protection of infected matter from flies, and, second, the protection of food, both liquid and solid, and the protection of the faces of infants and invalids from flies. The necessity of preventing flies from gaining access to excreta, infected or non-infected, is too obvious to need insisting upon, nor should flies have access to tubercular sputum or purulent discharges. The screening of food, of hospitals, of the sick room, and of infants is a measure which should be adopted as a matter of course rather than a hygienic necessity.

It is safe to say that, if measures were taken to prevent flies from breeding by doing away with possible breeding places, and also to prevent their transferring infection from infected material, the house fly would cease to be a serious factor in the carriage

of typhoid fever, tuberculosis, and intestinal diseases of infants.[1]

Control by Departments of Health. — Public nuisances may be abated by most health authorities and the breeding places thus abolished. The rules issued in the District of Columbia for this purpose have been summarized as follows:[1]

All stables in which animals are kept shall have the surface of the ground covered with a water-tight floor. Every person occupying a building where domestic animals are kept shall maintain in connection therewith a bin or pit for the reception of the manure, and, pending the removal from the premises of the manure from the animal or animals, shall place such manure in said bin or pit. This bin shall be so constructed as to exclude rain water, and shall in all other respects be water-tight except as it may be connected with the public sewer. It shall be provided with a suitable cover and constructed so as to prevent the ingress and egress of flies. No person owning a stable shall keep any manure or permit any manure to be kept in or upon any portion of the premises other than in the bin or pit described, nor shall he allow any such bin or pit to be overfilled or needlessly uncovered. Horse manure may be kept tightly rammed into well-covered barrels for the purpose of removal in such barrels. Every person keeping manure in the more densely populated parts of the District shall cause all such manure to be removed from the premises at least twice every week between June 1 and October 31, and at least once every week between November 1 and May 31 of the following year. No person shall remove or transport any manure over any public highway in any of the more densely populated parts of the District except in a tight vehicle which, if not inclosed, must be effectually covered with canvas, so as to prevent the manure from being dropped. No person shall deposit manure removed from the bins or pits within any of the more densely populated parts of the District without a permit from the health officer.

[1] Hewitt, C. G., *House-Flies and How They Spread Disease.*

Example of a City Fly Campaign. — As an example of what may be accomplished in a city against the house fly we can cite the results of a fly campaign that was carried on in Cleveland, Ohio, during the years 1912 and 1913. Interest was created in the public schools by the teachers and among the rest of the people through the newspapers. First, the over-wintering flies were attacked. Two hundred thousand fly swatters were distributed and ten cents per hundred flies was paid as a bounty. Fifty thousand mother flies were killed in this way, at a comparatively low cost. The citizens soon became sensitive to the presence of flies and as their numbers increased with the advance of summer, dealers in meats and provisions, and the proprietors of lunch rooms and restaurants were obliged to clean up the breeding places and kill off the adult flies if they wished to keep their customers. Many of the school children aided in the campaign. The boys joined the Junior Sanitary Police Force for the purpose of discovering unsanitary conditions in yards, alleys, and vacant lots, and the girls were organized as Sanitary Aides with the duty of decreasing the number of flies in stores where food was kept. "Before the close of the school year streets were cleaned, alleys and vacant lots ceased to be dumping grounds for filth, and the rubbish from back yards gave way to gardens of flowers and vegetables."[1] Any city can carry out a similar campaign, and many of them, in fact, are doing so.

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[1] Dawson, J., *Eliminating a City's Filth and Flies.*

CHAPTER IX

MOSQUITOES AND DISEASE

In many parts of the world mosquitoes are even more important than house flies as carriers of disease germs, but this has been known for only a few years. Two of the most dangerous of all diseases, malaria and yellow fever, are transmitted from one person to another only by mosquitoes, and several other diseases, such as dengue and elephantiasis, are spread, at least in part, by these insects. Besides this, mosquitoes are probably responsible for the transmission of germs with which we are not yet acquainted.

How Germs are Carried. — The mosquito differs from the house-fly in several important respects. In the first place, its mouth parts are fitted for piercing (Fig. 11, A), and it is thus able to penetrate the skin and suck blood directly from the body. Any germs that chance to be in the blood of the victim are thus taken into the alimentary canal of the mosquito and may be injected into the blood of the next person bitten. The house fly carries germs upon its body or in its alimentary canal, and is not itself diseased; it is called a *passive carrier*. The mosquito, on the other hand, is an *active carrier*. Its blood stream becomes filled with the germs, which are transported to the salivary glands, where they are stored up until the insect bites; then they pass with the saliva into the wound and infect the person bitten.

What the Germs Are. — These germs are not bacteria, as are those carried by the house fly, but minute animals called *Protozoa*. (See Chapter XXV.) Those which cause malaria are visible with the compound microscope, but the germs of yellow fever

have never been seen and we can only judge of their nature by comparing the disease they cause with other similar diseases.

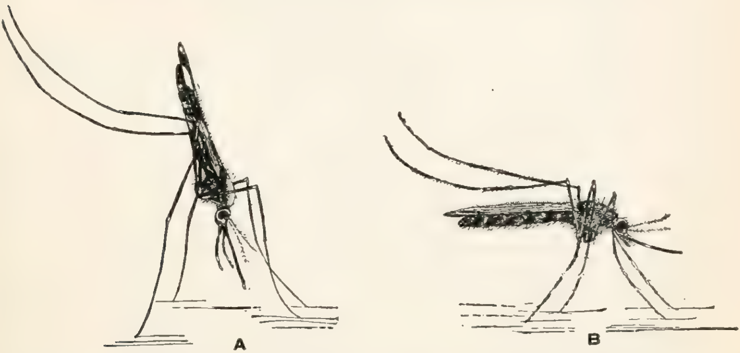

FIG. 53. — **A**, position of malaria mosquito (*Anopheles*) when at rest. **B**, position of common house mosquito (*Culex*) when at rest. (After Howard.)

THE MALARIAL MOSQUITO

Malarial fever is caused by minute parasitic Protozoa which attack the blood corpuscles causing "chills and fever." This was first demonstrated by a French army surgeon in Algiers in 1880. Three kinds of malaria are recognized: (1) Tertian

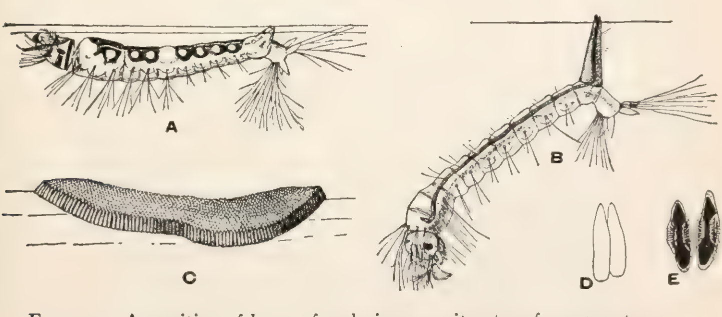

FIG. 54. — **A**, position of larva of malaria mosquito at surface of water. **B**, position of larva of common house mosquito at surface of water. **C**, raft of eggs of mosquito floating on surface of water. **D**, eggs of house mosquito; **E**, eggs of malaria mosquito. (After Howard.)

fever is the commonest; it is caused by a Protozoön named *Plasmodium vivax* and causes "chills and fever" every third day. (2) Quartan fever is due to *Plasmodium malariæ;* it causes "chills and fever" every fourth day. (3) Pernicious, tropical, or æstivo-autumnal fever is caused by *Plasmodium falciparum* and produces "chills and fever" at irregular intervals. Not all mosquitoes carry these germs, only those belonging to a group with the scientific name *Anopheles*. Fortunately *Culex* mosquitoes are more common than *Anopheles* mosquitoes

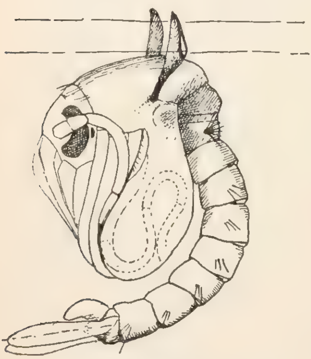

FIG. 55. — Pupa of house mosquito at surface of water.

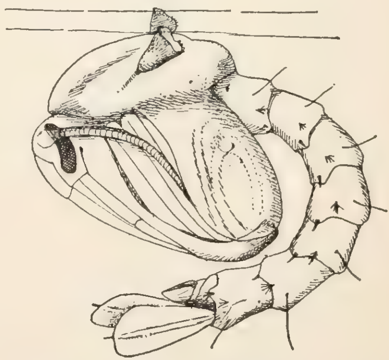

FIG. 56. — Pupa of malaria mosquito at surface of water. (After Howard.)

and are comparatively harmless. The two kinds can be distinguished by the position of the body when at rest; Anopheles holds its body at an angle, whereas Culex takes up a horizontal position, as shown in Figure 53. The eggs (Fig. 54, D and E), larvæ (Fig. 54, A and B), pupæ (Fig. 55), and adults differ also in various ways, such as size and structure.

Anopheles the Guilty Mosquito. — To prove that the Anopheles mosquitoes are guilty of transmitting the malarial fever parasite an English physician had some of these insects sent to him from a malarial district. He allowed them to bite him and in due time he became a victim of the fever. Two other English

physicians visited certain marshes in Italy where malaria was common and lived there for three months. Mosquitoes are not active by day but are nocturnal in habit. These physicians therefore went about outdoors freely during the daytime, but as evening approached, went indoors, where they were careful to protect themselves from being bitten. Neither of the men was bitten and neither of them contracted the disease, whereas their neighbors who did not protect themselves at night were afflicted with the fever as usual.

Losses Due to Malaria. — It is rather difficult to determine exactly the losses due to malaria. The annual death rate from malaria in the United States is about twelve thousand. There are, however, about three million cases every year, and since the productive capacity of a man suffering from the disease is reduced from fifty to seventy-five per cent, the loss is really appalling. But this does not include everything, for there is a loss to the country rising from the fact that many regions that are excellent for agricultural purposes cannot be developed because of the presence of malaria. After an investigation of this disease in the five states of Louisiana, Mississippi, Alabama, Georgia, and South Carolina, the following report was submitted:

We must now consider briefly what 635,000 or a million cases of chills and fever in one year mean. It is a self-evident truth that it means well for the physician. But for laboring men it means an immense loss of their time together with the doctors' fees in many instances. If members of their families other than themselves be affected, it may also mean a loss of time together with the doctors' fees. For the employer it means the loss of labor at a time perhaps when it would be of greatest value. If it does not mean the actual loss of labor to the employer, it will mean a loss in the efficiency of his labor. To the farmers it may mean the loss of their crops by want of cultivation. It will always mean the non-cultivation or imperfect cultivation of thousands of acres of valuable land. It means a

listless activity in the world's work that counts mightily against the wealth-producing power of the people. Finally it means from two to five million or more days of sickness with all its attendant distress, pain of body, and mental depression to some unfortunate individuals of those five states (Herrick).

Breeding Habits of Anopheles. — As in the case of the house fly, the breeding habits of the mosquito furnish the key for its destruction. Many kinds of mosquitoes lay their eggs in masses that float on the surface of the water (Fig. 54, C), but Anopheles deposits them singly, often close together (Fig. 54, E). The larvæ, which hatch from the eggs in about three days, remain in the water, feeding on the green scum on the surface. Their position in the water differs from that of other species, since they lie parallel to the surface (Fig. 54, A), whereas the larvæ of other mosquitoes hang from the surface at an angle (Fig. 54, B). At the posterior end of the body is a short breathing tube which is thrust through the surface film. In about two weeks the full-grown larvæ change to pupæ (Fig. 55). These must also remain near the surface, since they breathe through two tubes that look like ears and project from the thorax. The pupal stage lasts about four days, and then the adults emerge. The adults are active at night and only the females bite. During the winter mosquitoes hibernate in crevices as do the house flies.

Enemies of Mosquitoes. — Mosquitoes fall a prey to many natural enemies. The adults are devoured by certain night-flying birds, such as the nighthawk, by dragon flies (the so-called mosquito hawks), by spiders and toads, and by bats which fly about at dusk just when the mosquitoes begin to get active. The larvæ and pupæ are destroyed in countless numbers by insect-eating animals that live in the water, especially by small fish and by the large carnivorous insects, such as water scorpions, water beetles, and water boatmen. But while these enemies certainly decrease the number of mosquitoes, they are not able to prevent them from becoming a pest.

Control of Mosquitoes. — The Anopheles mosquito will breed wherever there is a small accumulation of water. Small creeks through meadow land, the ditches and gutters or drains along railroad and other embankments, and the shallow overgrown edges of ponds or swamp areas are favorite breeding places (Fig. 56). Pools containing grassy or other vegetation are nearly always infested, and ponds with lily pads, dock, sagittaria, and other plants of a similar character, are danger points. The

FIG. 57. — Oiling a pond near a railroad track where mosquitoes breed. (After Herms.)

larvæ need only a mere film of water, and this being found over a leaf or at a grassy edge, protects them from the usual natural enemies . . . no other mosquito has as wide a range of breeding places as have the species of Anopheles (Smith).

Two methods may be used to prevent mosquitoes from breeding in such places. The best method is to remove all receptacles in which water may collect and to drain all wet places. The other method is to treat the breeding places so as to kill the wigglers (larvæ and pupæ). Many different substances have been

tried with this end in view; the one used most in this country is a low grade of kerosene oil. An ounce of oil will spread over about fifteen square feet of surface, and the film thus formed will destroy all wigglers and many of the adults which come to drink or lay eggs. Such a film will persist for about ten days. Oil may be applied to small bodies of water with a watering pot and to larger surfaces with a spray pump.

Example of Mosquito Control. — As an example of the results of work carried on in this way the antimalarial campaign waged in Havana during the American occupation of 1901 to 1902 may be cited. An Anopheles brigade of workmen was organized under the sanitary officer, Doctor Gorgas, for work along the small streams, irrigated gardens, and similar places in the suburbs, and numbered from 50 to 300 men. No extensive drainage, such as would require engineering skill, was attempted, and the natural streams and gutters were simply cleared of obstructions and grass, while superficial ditches were made through the irrigated meadows. Among the suburban truck gardens Anopheles bred everywhere, in the little puddles of water, cow tracks, horse tracks, and similar depressions in grassy ground. Little or no oil was used by the Anopheles brigade, since it was found in practice a simple matter to drain these places. At the end of the year it was very difficult to find water containing mosquito larvæ anywhere in the suburbs, and the effect upon malarial statistics was striking. In 1900, the year before the beginning of the mosquito work, there were 325 deaths from malaria; in 1901, the first year of the mosquito work, 171 deaths; in 1902, the second year of mosquito work, 77 deaths. Since 1902 there has been a gradual though slower decrease, as follows: 1903, 51; 1904, 44; 1905, 32; 1906, 26; 1907, 23.[1]

Driving Away Mosquitoes. — Mosquitoes not only carry the germs of many diseases, but they are at all times disagreeable companions, often rendering the most charming localities unin-

[1] Howard, L. O., *Economic Losses to the People of the United States through Insects that Carry Disease.*

habitable during the summer. Various preventives have been devised to drive them away. Mixtures of camphor, oil of citronella, and cedar oil when applied to the face and hands will protect one for a few hours; dense smoke will drive them away; and several sorts of gases will expel them from houses, such as burning sulphur, orange peel, or insect powder (pyrethrum). Mosquito bites may be relieved by an application of moist soap, ammonia, alcohol, or glycerin.

The Yellow Fever Mosquito

In 1901 the mosquito known to science as *Stegomyia calopus* was proved to be the carrier of yellow fever. This mosquito lives in tropical and semi-tropical countries, and differs from the ordinary Culex and Anopheles mosquitoes in its habit of biting in the daytime. It will breed in any kind of water and in small amounts, so that the methods of destroying the larvæ and pupæ are like those employed for the Anopheles mosquito. Outbreaks of yellow fever have occurred in many cities in this country. Philadelphia suffered a severe epidemic in 1793; New Orleans lost 8000 in the epidemic of 1853; in 1878 there were 125,000 cases and 12,000 deaths in the Southern States.

Control in New Orleans. — The last serious outbreak took place in New Orleans in 1905, and its history serves to illustrate the value of the methods of attacking the problems that were then just recently acquired. The presence of yellow fever in the city was first recognized about the 12th of July, and the plan of campaign adopted was based on the theory that mosquitoes carried the disease. By the 12th of August the increase in the new cases and deaths rendered it practically certain that the disease was as widespread as during the terrible epidemic of 1878. There had been up to that time 142 deaths from a total of 913 cases, as against 152 deaths from a total of 519 cases in 1878. The work for the rest of the summer was continued with

great energy and the measures were based almost entirely upon a warfare against the yellow fever mosquito. The disease began almost immediately to abate, and the result at the close of the season indicated 460 deaths, as against 4046 in 1878, a virtual saving of over 3500 lives.[1]

Control in Panama Canal Zone. — One of the most interesting examples of the eradication of disease by the destruction of mosquitoes is the campaign of the United States Government in the Panama Canal Zone which was begun in 1904.[1]

In Panama, as in Havana, the population had depended principally upon rain water for domestic purposes, so that every house had cisterns, water barrels, and such receptacles for catching and storing rain water. The city was divided into small districts with an inspector in charge of each district. This inspector was required to cover his territory at least twice a week and to make a report upon each building with regard to its condition as to breeding places of mosquitoes. All the cisterns, water barrels, and other water receptacles in Panama were covered as in Havana, and in the water barrels spigots were inserted so that the covers would not have to be taken off. Upon first inspection, in March, 4000 breeding places were reported. At the end of October less than 400 containing larvæ were recorded. This gives one a fair idea of the consequent rapid decrease in the number of mosquitoes in the city. These operations were directed primarily against the yellow fever mosquito, and incidentally against the other common species that inhabit rain-water barrels. Against the Anopheles in the suburbs the same kind of work was done as was done in Havana, with exceptionally good results.

The same operations were carried on in the villages between Panama and Colon. There are some twenty of these villages, running from 500 to 3000 inhabitants each. Not a single in-

[1] Howard, L. O., Bulletin 78, Bureau of Entomology, U. S. Department of Agriculture.

stance of failure has occurred in the disinfection of these small towns, and the result of the whole work has been the apparent elimination of yellow fever and the very great reduction of malarial fever.

The remarkable character of these results can only be judged accurately by comparative methods. It is well known that during the French occupation there was an enormous mortality among the European employees, and this was a vital factor in the failure of the work.

Control by School Children. — That children can be of immense service in freeing a city from mosquitoes as well as from house flies (see Chap. VIII) is illustrated by certain events that took place in San Antonio, Texas. Yellow fever appeared in this city in November, 1903, and although its presence was denied by the inhabitants, efforts were made by certain enlightened people to eradicate it as soon as possible by destroying all the mosquitoes. In this campaign the aid of the school children was enlisted with excellent results.

The best recent literature on the subject of fighting mosquitoes was procured and furnished to the teachers, and a circular letter was sent to them outlining a proposed course and offering a cash prize for the best model lesson on the subject. Teachers became deeply interested. A crude aquarium, with mosquito eggs and larvæ was kept in every schoolroom, where the pupils could watch them develop, and large magnifying glasses were furnished in order that they might study to better advantage. The children were encouraged to make drawings on the blackboard of mosquitoes in all stages of development. Lessons were given and compositions were written on the subject. Competitive examinations were held, and groups of boys and girls were sent out with the teachers on searching expeditions to find the breeding places. Rivalry sprung up between the ten thousand public school children of the city in the matter of finding and reporting to the health office the greatest number of breeding places found and breeding-places destroyed. Record was kept

on the blackboards in the schools for information as to the progress of the competition, and great enthusiasm was stirred up. In addition to these measures, a course of stereopticon lectures was arranged, which the pupils attended in groups of about one thousand.

The result of this work, it is pleasing to say, was a decided diminution of mosquitoes in San Antonio. There was some opposition from the people, but on the whole the movement was very popular. One result of this work was that, whereas previously there had been from fifty to sixty deaths a year from malaria, this mortality was reduced seventy-five per cent the first year after the work was begun, and in the second year it was entirely eliminated from the mortality records of San Antonio.

In organizing community work against mosquitoes, the school children hereafter must be counted upon as a most important factor. Almost every child is a born naturalist, and interest in such things comes to children more readily than anything else outside of the necessities of life. They are quick-witted, wonderfully quick-sighted, and as finders out of breeding places they usually cannot be approached except by adults of special training. One of the first steps that a community should take is, therefore, to arouse the interest of the children in the public schools (Howard).

Mosquitoes and Other Diseases. — There are many other tropical diseases caused by minute living things that are probably transmitted by mosquitoes, although we have yet to learn how guilty these insects really are. A great many scientists are now employed in the study of these diseases and we may hope that as a result of their studies the tropics in the near future will be as healthful as any other part of the world. The cause of dengue or breakbone fever is not known, although it is supposed to be a germ similar to those present in malaria and yellow fever. Whatever it is, it is known to be transmitted by mosquitoes. Elephantiasis is a disease caused by minute worms (see Chap. XX) which occur in vast numbers in the blood of human

beings, causing immense swellings of various parts of the body. These parasitic worms are probably injected into the body of the victim when an infected mosquito bites him.

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CHAPTER X

OTHER INSECTS THAT TRANSMIT DISEASE GERMS

The insects other than house flies and mosquitoes that transmit disease germs are principally blood-sucking flies, fleas, bedbugs, and lice. The relations of many of these insects to disease are very little known, but in a few years we may expect the jury of scientists either to convict or acquit those now under indictment.

Fleas and Bubonic Plague. — The connection between fleas and bubonic plague is now well known. This disease is caused by a very small bacterium which causes fever, glandular swellings, and often death. Many epidemics are recorded in history; in the sixth century about half of the people in the Roman Empire died of it; in India from 1901 to 1904 it caused about two million deaths; and in China, Egypt, South Africa, and in our own seaports epidemics have occurred or have been threatened. Careful studies of the plague have proved that the bacteria causing it are chiefly carried from diseased rats to man by a kind of flea which is now known as the plague flea.

Control of Plague in San Francisco. — In the neighborhood of San Francisco the California ground squirrels have also become diseased by plague germs that have been transferred to them by rat fleas. The spread of the disease throughout North America through the agency of ground squirrels, rats, and fleas is thus made possible.

" During the last few years San Francisco has been fighting an outbreak of plague that in other days would have been nothing less than a national calamity. But with modern methods of handling it, based on knowing what it is, what causes

it, and how it is spread, the authorities there have been able not only to hold the disease in check, but practically to stamp it out with the loss of comparatively few lives.

" A small army of men was employed, catching rats in every quarter of the city. Dr. Rucker reports that fully a million rats were slain in this campaign. Their breeding places were destroyed by making cellars, woodshed, warehouses, etc., rat-proof and removing all old rubbish. Garbage cans were installed in all parts of the city, as it was required that all garbage be stored where rats could not feed upon it, and altogether every effort was made to make it as uncomfortable as possible for the rats.

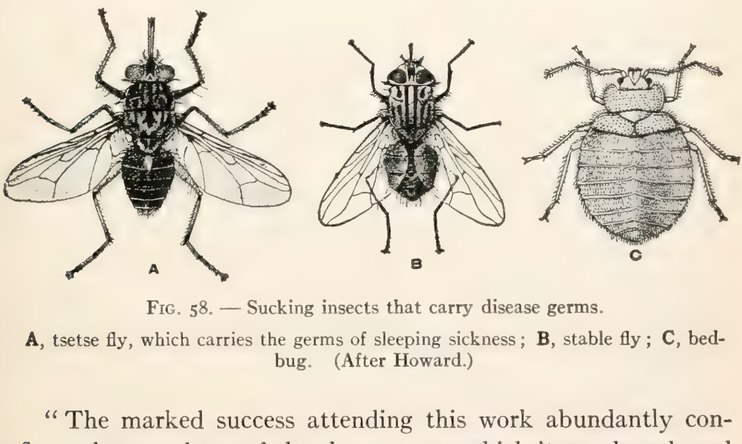

FIG. 58. — Sucking insects that carry disease germs.

A, tsetse fly, which carries the germs of sleeping sickness; **B**, stable fly; **C**, bed-bug. (After Howard.)

" The marked success attending this work abundantly confirms the soundness of the theory upon which it was based, and serves as another example of the way in which science is teaching us how to prevent or control many of our most serious diseases." (Doane.)

Blood-sucking Flies and Disease. — Blood-sucking flies are known to transmit the germs of sleeping sickness, and probably carry those of infantile paralysis (polyomyelitis) and anthrax. *Sleeping sickness* is prevalent in certain parts of tropical Africa. It is caused by a minute protozoan parasite and is transmitted

from one person to another by the tsetse fly (Fig. 58, A). *Infantile paralysis* is a disease that is often epidemic in this country. The results of recent investigations have proved that it may be transmitted from a diseased monkey to a healthy one by bites of the common stable fly, and it seems very probable that these flies also transmit it from one human being to another. The stable fly (Fig. 58, B) is frequently abundant around houses and is often mistaken for the house fly; bites often credited to the latter are really made by the stable fly, since the house fly cannot pierce the skin (see page 76).

Anthrax is the most widely spread of all infectious diseases. It occurs almost all over the world, and attacks man, horses, rabbits, and other mammals, but especially cattle and sheep. The bacillus (Fig. 48, D) is comparatively large, being about $\frac{1}{3500}$ of an inch long. Anthrax is especially interesting, since it was the first disease proved (by Pasteur and Koch) to be caused by bacteria. Blood-sucking flies are probably concerned in the transmission of the anthrax germs, since the bacilli often enter the body in wounds and are found in the blood of most of the infected animals. Vaccination according to the methods devised by Pasteur in 1881 is employed for cattle and sheep in infected districts with good results. In France alone, between the years 1882 and 1907, 8,000,000 sheep and 1,300,000 cattle were vaccinated.

Bedbug and Disease. — The guilt of the bedbug, so far as the transmission of disease germs is concerned, has not been fully determined. Bedbugs (Fig. 58, C) are thoroughly domesticated, living only in human dwellings. During the day they hide in cracks, but at night they sally forth to suck the blood of any unfortunate being that they chance to find. Gasoline, corrosive sublimate, or turpentine, if injected into their hiding places, will kill them. Bedbugs are accused of transmitting the germs of leprosy, Oriental sore, and the dumdum fever or kala-azar of the tropics.

Sucking Lice and Disease. — The sucking lice that occasion-

ally parasitize human beings (see p. 54) are, like the bedbug, in an uncertain position. It is evident that their mode of life is such as to make the transmission of germs by them an easy matter. Recent reports seem to prove that body lice (Fig. 34, D) are the only carriers of the germs of relapsing or recurrent fever which occurs occasionally in America, but is prevalent in Central Africa.

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CHAPTER XI

CLASSIFICATION IN GENERAL AND OF INSECTS IN PARTICULAR

When one has a large number of different kinds of objects before him, it is but natural for him to try to arrange them in some orderly fashion. If a person unacquainted with insects were given several hundred of them, he would have little difficulty in separating them into groups of butterflies, beetles, flies, etc., which would, at least approximately, coincide with the groups in which these insects are placed by scientists. What such a person does is to pick out some characteristic that seems to be general, such as the large, beautifully colored wings of the butterfly or the hard, sheathlike wings of the beetle.

Artificial Classification. — A study of the habitats of insects has shown that (1) some live on the surface of the ground; (2) some burrow in the ground; (3) some live in the waters of ponds and streams; (4) some fly about in the air much of the time; (5) and many live on or in the bodies of other animals. We can classify these insects according to their habitats as terrestrial, subterrestrial, aquatic, aërial, and parasitic, but a group collected from any one habitat will exhibit among themselves a great diversity in characteristics. This sort of classification is called artificial.

Natural Classification. — A natural classification attempts to place every animal in its proper place according to its kinship with other kinds of animals. The grouping of insects employed in the preceding chapters is artificial since, for example, under the heading of insects of the household we mentioned among others

the meal worm (a *beetle*) and carpet *beetle*, the black and red *ants*, the cheese skipper (a *fly*), house *fly*, and stable *fly*, and the clothes *moth*. The adults of these insects would unhesitatingly be placed with their proper relatives by any one, — the ants in one group, the beetles in another, etc., but a very close examination is necessary in many cases before we can actually determine the correct position of an animal with regard to other kinds of animals.

General Knowledge of Principal Groups. — Thus far we have discussed insects almost exclusively, although it has been necessary for us to mention other animals, such as birds, horses, dogs, cats, and man. That there is a very great difference between insects and these other animals is quite obvious and even those who have never studied the way animals are grouped are familiar in a general way with the popular names applied to many of the larger assemblages. Thus children speak of insects, worms, fishes, reptiles, and birds without realizing the significance of the terms.

Structure and Life Histories in Classification. — The error is commonly made of calling anything that resembles an earthworm in general appearance a worm, but we have seen that the young of many insects, that is, larvæ, are wormlike. These larvæ are commonly called worms, but of course are very far removed from the earthworm in the scale of life, since they later become highly organized insects, whereas the earthworm remains a worm as long as it lives. A comparison between the structure of the earthworm and the insect larva would reveal many fundamental differences, and a study of their life histories would quickly prove that the two are really very distant relatives. This shows that we must be acquainted with both an animal's structure and its life history before we can be certain of its relations to other animals.

System of Classification Used by Scientists. — The system of classification now in use was devised by the Swedish naturalist Linnæus (1707–1778). He divided the animal kingdom into a

number of large groups called *phyla*. The animals in each phylum were subdivided into groups called *classes;* the classes into subgroups, the *orders;* the orders into *families;* the families into *genera;* and the genera into *species*. *Each species consists of a group of closely similar individuals.* By referring to animals familiar to every one it will be possible to make the system of classification used by scientists perfectly clear.

Horse as an Example of Species. — The common horse, although represented by over sixty domesticated races, belongs to a single species which is known to scientists as *Equus caballus*. The term "caballus" is used only for the common horse, but the term *Equus* is also employed when writing of certain near relatives of the horse, such as the zebra, *Equus zebra*.

Equus is known as the generic name, and the horse and zebra are said to belong to the same genus. The horse and zebra, together with a number of other horselike animals, make up the *genus Equus*. *A genus may be defined as a group of similar species.*

As in the case of the horse, every species is referred to in scientific writings by two terms: the generic name comes first and is written with a capital; the specific name second with a small letter. These two terms are often followed by the name of the scientist who first applied the name to any particular animal.

The genus *Equus*, the extinct genus *Protohippus*, and several other genera are grouped together into one family, the horse *family Equidæ*.

This family and several others, including the family *Tapiridæ*, which contains the tapirs, and the family *Rhinocerotidæ*, which contains the rhinoceroses, belong to the *order Perissodactyla*. All of the animals in this order have an odd number of toes, and each toe bears a hoof.

The order *Perissodactyla* belongs with the order *Rodentia* (gnawing animals, like the rabbit and mouse), the order *Carnivora* (flesh-eating animals, such as the cat and dog), the order

Primates (monkeys, apes, and man), and a number of other orders in one class, the *class Mammalia*. The members of this class are called mammals, and all have certain characteristics in common; among these are a covering of hair, and the presence of milk glands from which the helpless young obtain food.

The animals in the class *Mammalia* and in the classes containing the birds, reptiles, fish, and eels resemble one another in the possession of a backbone, made up of a series of bones called vertebræ, and are hence grouped together in the *phylum Vertebrata*. The vertebrates are the only animals that possess a backbone.

The rest of the animals in the animal kingdom are arranged in a similar way and we may recognize ten phyla in all as indicated on page 6.

The system described above may be applied to man as follows:

George Washington was an individual; he belonged, with other men, to the species *sapiens* of the genus *Homo*. This genus, together with another of somewhat questionable relationships, the extinct *Pithecanthropus*, constitutes the family *Hominidæ*. The *Hominidæ* are included with ten other families of monkey-like animals in the order *Primates*. Fifteen related orders, of which the *Primates* form one, are placed in the class *Mammalia*. The class *Mammalia* with four other classes make up the phylum *Vertebrata*. The scientific name of man is written *Homo sapiens* Linnæus.

Reasons for Existence of Classification. — There are several important reasons why a classification of animals exists. In the first place it seems natural for us to group similar things together, and this has been done ever since the time of the Greek naturalist Aristotle (384–322 B.C.) who gave us the first valuable writings on animals. For example, we are all the time unconsciously classifying human beings, grouping them into nations, such as the English, French, German, etc., or into races, as the

white, black, red, etc., or, according to locality, into Eastern, Northern, Southern, etc.

Besides this we are able by means of our system to learn the name of an animal new to us; and if it is one that has never before been named and recorded, we can soon learn this, give it a name, and add it to the list. Furthermore, scientists are at all times making detailed studies of the animals already known and are constantly rearranging them so as to establish their kinship.

Value of Classification as Mental Training. — The study of classification if carried out in the laboratory will influence one's entire life. It will teach one to make observations and comparisons and to do so with accuracy. It will also teach the value of arranging facts systematically — a lesson which, once learned regarding animals, will be applied to other things throughout life.

Necessity of Scientific Terms. — Many people do not understand why scientific terms are necessary, since our common animals are known by plain English names, such as horse and robin. Science, however, does not recognize the boundaries of nations but is world-wide, and we must be able to understand the writings of the Germans, French, and others, as well as those in our own language. For this reason scientific terms are the same all over the world. They are Latin in form, and derived chiefly from the Latin and Greek.

In many cases the scientific term is simply the Latin name of the animal; for example, the American toad is known everywhere as *Bufo americanus*, *bufo* meaning toad in Latin, and *americanus*, American. Some animals are named because of their geographical distribution, like the California sea lion, *Zalophus californianus*, which lives in that region. Or the name may describe the animal in some way. The *rufus* in the wildcat's name, *Lynx rufus*, is descriptive of the animal's rufus color, and the *sapiens* in the name of man, *Homo sapiens*, is the Latin word meaning wise and describes his mental condition. And

finally scientists often name species of animals after some one who has become an authority in the subject; for example, one of our common hawks was named *Buteo swainsoni* in honor of the bird student Swainson.

Classification of Insects. — It would seem as though the value of our system of classification could be thoroughly tested by means of the insects, since this group of about four hundred thousand known species of animals constitutes a *single class*, the *Insecta*. The *class Insecta* is included in the *phylum Arthropoda* along with three other classes, the *Crustacea* (crayfish, lobster, etc.), *Myriapoda* (thousand-legged worms, etc.), and *Arachnida* (spiders, mites, etc.). These classes are also larger than most other classes in the animal kingdom, and hence the arrangement of the members of this one phylum *Arthropoda* might be expected to be rather difficult. But while it is true that we still do not know exactly where a few of the arthropods belong, most of them fit into their places without difficulty.

Characteristics of the Class Insecta. — The members of the class *Insecta* are characterized by the presence of one pair of antennæ, three pairs of legs, and usually wings. The crayfish is not an insect, for it has two pairs of antennæ, five pairs of legs, and no wings. The spiders are not insects since they have four pairs of legs and no antennæ, and the thousand-legged worms are not insects because they have a great many pairs of legs and no wings. All of these animals belong to the phylum *Arthropoda*, however, because they have an outer covering or exoskeleton of chitin instead of a backbone, have a body divided more or less distinctly into similar parts (segments) arranged in a linear series, and possess paired, jointed appendages (legs, etc.) on some or all of the segments.

Orders of Insects. — Insects have been divided into eight orders according to (1) the presence or absence of wings, and their number and structure when present, (2) the structure of the mouth parts (biting or sucking), and (3) the character of the metamorphosis. Although some of the orders would have

to be divided into two or more if we were going to study insects in detail, the main orders of insects with their characteristics, are as follows.

Order 1. Aptera. — Fish Moths and Springtails.

Primitive insects without wings or rudiments of wings; biting mouth parts; and no metamorphosis.

The fish moth or silver fish is the commonest species (see p. 57, Fig. 35, A). The snow flea is sometimes a pest in maple sugar camps, since large numbers often get into the sap.

Order 2. Orthoptera. — Grasshoppers, Crickets, etc.

Insects with four wings; the fore wings straight and leathery; the hind wings folded like a fan; biting mouth parts; metamorphosis direct.

The principal families of the Orthoptera are the (1) cockroaches, (2) mantids, (3) walking sticks, (4) grasshoppers or locusts with short antennæ,(5) grasshoppers with long antennæ; and (6) crickets.

Order 3. Neuroptera. — May Flies, Dragon Flies, etc.

Insects with two pairs of membranous wings; biting mouth parts; metamorphosis direct or indirect.

The group of insects included here are the May flies, dragon flies, stone flies, caddice flies, lacewing flies, and white ants or termites.

Order 4. Hemiptera. — Chinch Bugs, Scale Insects, etc.

Insects with four wings, or degenerate and without any wings; the fore wings of some thickened at the base; sucking mouth parts; metamorphosis direct.

These are the true bugs. The wingless species are the sucking lice, bedbugs, and many scale insects. The winged species include the cicadas, tree hoppers, spittle insects, water striders, chinch bugs, squash bugs, and stink bugs.

Order 5. Lepidoptera. — Butterflies, Skippers, and Moths.

Insects with four membranous wings covered with scales; usually sucking mouth parts; metamorphosis indirect.

These insects are noted for their brilliant colors. The butter-

flies and skippers are active during the day, that is, they are *diurnal*, and the moths at night (*nocturnal*). The members of the three main groups can be distinguished by their antennæ; those of the butterflies end in a knob, of the skippers in a knob with a recurved point, and of the moths without the knob but often with bristles on the sides.

Order 6. DIPTERA. — House Flies, Mosquitoes, etc.

Insects with the two fore wings present, but the two hind wings represented by knobs; sucking mouth parts; metamorphosis indirect.

Some of the Diptera are degenerate and without wings, such as the bird lice, fleas, and sheep tick; the winged species include the house flies, mosquitoes, crane flies, midges, gnats, horse flies, botflies, and flower flies.

Order 7. COLEOPTERA. — Beetles.

Insects with four wings, the fore wings (called elytra) sheath-like and covering the membranous hind wings; biting mouth parts; metamorphosis indirect.

This is a very large order in number of species. Some of the common families are the tiger beetles, ground beetles, whirligig beetles, burying beetles, click beetles, scarabid beetles, June bugs, potato beetles, ladybird beetles, bark beetles, weevils, meal-worm beetles, Spanish flies, and fireflies.

Order 8. HYMENOPTERA. — Ants, Bees, Wasps, etc.

Insects with four membranous wings; mouth parts both for biting and sucking; sting often present; metamorphosis indirect.

This is another very large order. Some of the principal families are the ants, bees, wasps, sawflies, gallflies, ichneumon flies, and chalcid flies.

It is evident from the above list that in many cases one could not tell from the common names where the insects belong. For example, the true flies are the *Diptera*, but some of the members of almost every other order are called flies, such as the May flies, butterflies, fireflies, and sawflies. To most people an insect

is a bug, but only those belonging to the order *Hemiptera* are true bugs.

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CHAPTER XII

SPIDERS AND OTHER ARACHNIDS

Where Spiders Live. — Spiders are considered " insects " by many people, but they can be distinguished easily from them by the presence of four pairs of legs instead of only three, and by the union of the head and thorax into one piece, called the cephalothorax. There are probably four or five hundred different kinds of spiders living in the neighborhood of any city of the United States. They are to be found in all sorts of places. Many species live almost entirely around houses, making their webs in the corners of the rooms, in the cellars, or outside in window corners, crevices in walls, etc. Other species make their homes under stones and sticks lying on the ground. Plants of all kinds are alive with spiders, some preferring grass, and others bushes or trees.

Spiders with and without Webs. — We always associate spiders with spider webs, but a great many species which are called hunting spiders do not build webs. They have nests, but run about catching insects wherever they chance to find them or lie in some place of concealment until insects come within their reach.

Types of Webs. — The cobweb spiders build webs for catching insects, and live either in the web or in a nest close to it. Cobwebs are of four principal kinds: —

1. The flat webs are closely woven of long threads crossed by finer ones in all directions, and connected with a tubular nest where the spider hides, and from which it runs out on the upper side of the web after insects that may fall upon it.

2. The netlike webs are made of smooth threads in large meshes, sometimes in a flat or curved sheet held out by threads

FIG. 59. — Photograph of a spider at the center of its web. (After Burlend.)

in all directions. The spider lives on the underside, back downward.

3. The round webs are made of threads radiating from a common center and crossed by circular loops and spirals, part of which are adhesive (Fig. 59).

4. The webs of certain species are composed in part of loose bands of silk (Emerton).

How Webs are Built. — An orb web, such as that shown in Figure 59, is spun in the following manner: A thread is stretched across the space selected for the web; then from a point on this thread other threads are drawn out and attached in radiating lines. These threads all become dry and smooth. On this foundation a spiral is spun of sticky thread (Fig. 61, D). The

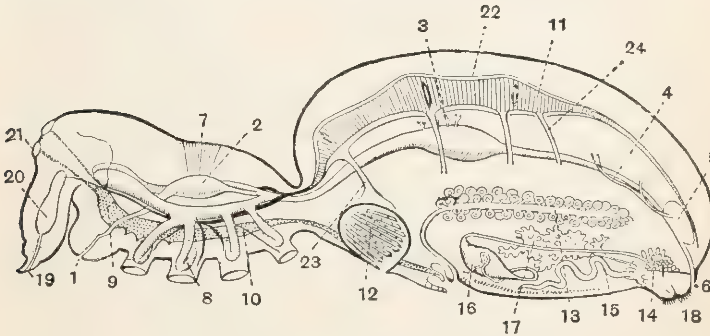

FIG. 60. — Internal anatomy of a spider.

1, mouth; **2**, sucking stomach; **3**, ducts of liver; **4**, so-called malpighian tubules; **5**, stercoral pocket; **6**, anus; **7**, dorsal muscle of sucking stomach; **8**, cæcal prolongation of stomach; **9**, cerebral ganglion giving off nerves to eyes; **10**, subœsophageal ganglionic mass; **11**, heart with three lateral openings or ostia; **12**, lung sac; **13**, ovary; **14**, **15**, **16**, **17**, silk glands; **18**, spinnerets; **19**, distal joint of chelicera; **20**, poison gland; **21**, eye; **22**, pericardium; **23**, vessel bringing blood from lung sac to pericardium; **24**, artery. (From the Cambridge Natural History.)

spider stands in the center of the web or retires to a nest at one side and waits for an insect to become entangled in the sticky thread; it then rushes out and spins threads about its prey until all struggles cease.

Spinning Organs. — The spinning organs of spiders, called spinnerets, are three pairs of projections near the posterior end of the body on the ventral surface (Fig. 61, A). The spinnerets are pierced by hundreds of microscopic tubes through which a fluid passes from the silk glands (Fig. 60, *14*, *15*, *16*, *17*), which

hardens in the air, forming a thread. The silk glands are situated in the abdomen and cause the large size of this part of the body.

How Insects are Captured. — The webs of the cobweb spiders catch many small animals, mostly insects, but the spider itself never seems to become entangled in its own web. This is probably because of the peculiar structure of the foot (Fig. 61, B). The hunting spiders live principally on insects. The struggles of the captured animals are soon stopped by a poisonous secretion which is injected into them. This poison is formed in poison glands situated in the head (Fig. 60, *20*), and forced out through the first pair of appendages, the cheliceræ (Fig. 60, *19*). When the captured insect has become quiet, the spiders suck out the juices into the alimentary canal by means of a sucking stomach (Fig. 60, *2*).

Sense Organs. — Spiders are, of course, aided by sense organs in obtaining their food. Hairs that are sensitive to touch are generally distributed over the body. The eyes, however, are the principal organs of sense. There are usually eight (Fig. 61, C), and they differ in size and arrangement in different species. Spiders apparently can see objects distinctly only at a distance of four or five inches.

Respiration. — Since spiders are terrestrial animals, they must be able to breathe in the air. For this purpose they are supplied with tracheæ similar to those of insects (see p. 15), but in addition they possess book lungs which are present only in spiders. The book lungs (Fig. 60, *12*), of which there are usually two, are sacs, each containing generally from fifteen to twenty leaf-like horizontal shelves through which the blood circulates. Air, entering through the external openings, is thus brought into close relationship with the blood.

Reproduction. — The eggs of spiders are inclosed in a silk cocoon which varies much in shape and color in different species. Some spiders hang it in the web, others attach it to plants or stones, and others carry it with them, either in the mandibles or attached to the spinnerets. The young remain in the cocoon

until they are able to run about, and after coming out of the cocoon keep together for a short time, sometimes in a web which they make in common, sometimes in a web made by the mother, and in some species on the mother's back, but they soon scatter and hunt their own food or make cobwebs, according to the habits of the species (Emerton).

Spiders are among the most interesting of all animals because of their remarkable methods of building their webs, of distributing themselves, and of capturing their prey.

Aërial Spiders. — On sunny days in autumn large numbers of fine threads, the so-called gossamer threads, may be seen floating about over fields and meadows. On some of these threads, if we examine them, we shall find a small (young) spider. This aërial vehicle is of the creature's own construction, having been produced in the following manner: Having ascended some elevated spot, such as a clod of earth, the spider spins a few short threads, which are fastened to the ground. These it grasps in order to obtain a firm hold. Next it once more presses the silk glands against the supporting surface, and elevates its abdomen. In

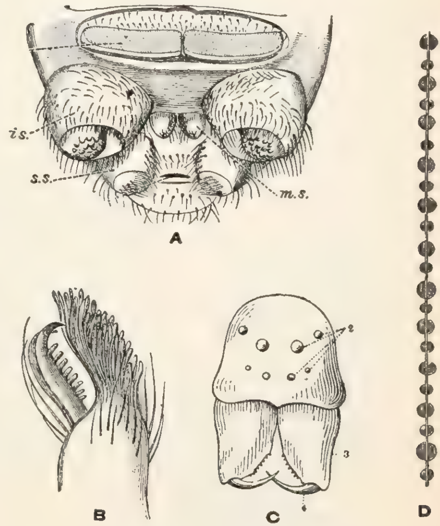

FIG. 61. — Parts of a spider's body.

A, ventral view of posterior end of abdomen showing three pairs of spinnerets (*is*, *m.s.*, and *s.s.*).
B, foot showing claws and bristles.
C, front of head showing eyes (**2**) and jaws (**3** and **4**).
D, a thread from a spider's web. (After Warburton.)

this way a thread is formed, which, soon being seized by the wind, is drawn out longer and longer, blown hither and thither, and thrown into tangles, so that finally a small raft is produced. At last the wind lifts both the raft and its maker up into the air, and the aërial journey begins. Perchance the little ship will be stranded — agreeably to the wish of its navigator — in some spot

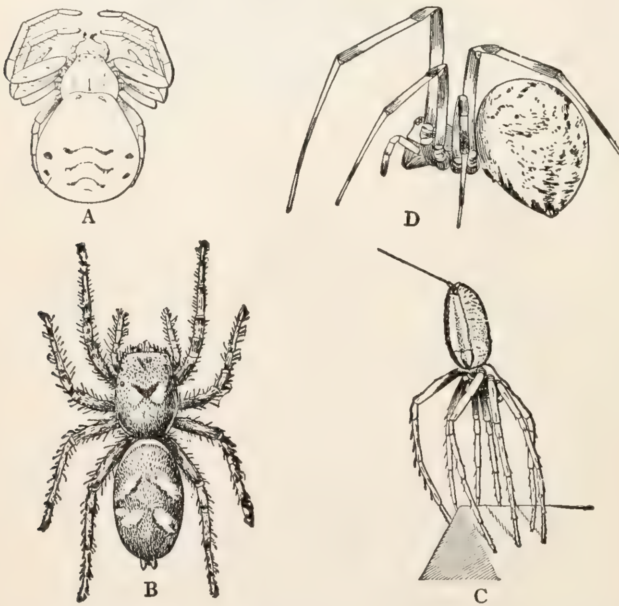

FIG. 62. — **A**, crab-spider; **B**, jumping-spider; **C**, young spider preparing for an aërial voyage; **D**, house-spider. (After Emerton.)

where the latter may enjoy its winter rest in security, in order in the following year to spread its species (Fig. 62, C) (Schmeil).

Water Spider. — The water spider of Europe lives under water. Its abdomen has a velvety covering of hairs, and just as a layer of air remains adherent to a velvet rag dipped in water, so this spider always carries a large silvery air bubble down with it below the water. There it spins a dwelling not unlike a small

diving bell, which it anchors by threads to water plants, and fills with air in the aforesaid manner. Thus the animal lives in air in the midst of the water! (Schmeil).

Trapdoor Spider. — The nests of the trapdoor spider, often seen in collections of curios, usually come from California. The spider which makes the nest is blackish brown in color and measures a little over an inch in length. A cylindrical tunnel is dug in the ground, the walls of which are made firm by gluelike

FIG. 63. — **A**, tarantula; **B**, trapdoor spider. (From Coleman.)

saliva, and then lined with silk (Fig. 63, B). The entrance to this tunnel is covered by a hinged door. From this place of concealment the spider ventures out after its prey, returning at the first sign of danger. The top of the door resembles the surrounding earth, so that the nests are hard to find. If the spider is discovered, it holds the door shut from within and is dislodged with difficulty.

Tarantulas. — Certain large, hairy spiders that live in warm parts of the world are commonly called tarantulas (Fig. 63, A). These spiders are supposed to be very poisonous, but most of the stories told about them are not true, since they very seldom bite, and if they do, the injury is probably no worse than the sting of a bee.

Spider Bites. — In the North there is no danger at all from spider bites. Spiders if captured are so busy trying to escape that they rarely attempt to bite. They use poison to kill insects, but scientists have allowed themselves to be bitten by all kinds of spiders without any harmful results whatever. Evidently a dose of poison that will paralyze an insect has no effect

FIG. 64. — A harvestman. (From Sedgwick.)

upon a man. It is therefore perfectly safe to handle any living spiders if you so desire.

Harvestmen. — The harvestmen or daddy longlegs (Fig. 64) resemble spiders in many ways. They possess small bodies and very long, slender legs. During the daytime they remain quietly in some place of concealment, but at night they venture forth in search of insects whose juices they suck just as do the spiders.

Scorpions. — Scorpions are rapacious arachnids measuring from half an inch to eight inches in length (Fig. 65). They live in tropical and subtropical regions, hiding in crevices or in pits in the sand during the daytime, but running about actively at night. They capture insects and spiders with their pinchers, tear them apart with their cheliceræ, and devour the pieces. Larger animals are paralyzed by the sting on the end of the tail. This sting does not serve as a weapon of defense unless the scorpion is hard pressed, and is not used, as is often stated, to sting itself to death, since the poison has no effect upon its own body.

Mites and Ticks. — The mites and ticks are small arachnids living on vegetation, in the water, or as parasites on men and other animals. They will be more fully discussed in the next chapter.

King Crab. — The king or horseshoe crab (Fig. 66) is a peculiar arachnid that lives in the sea and was for a long time con-

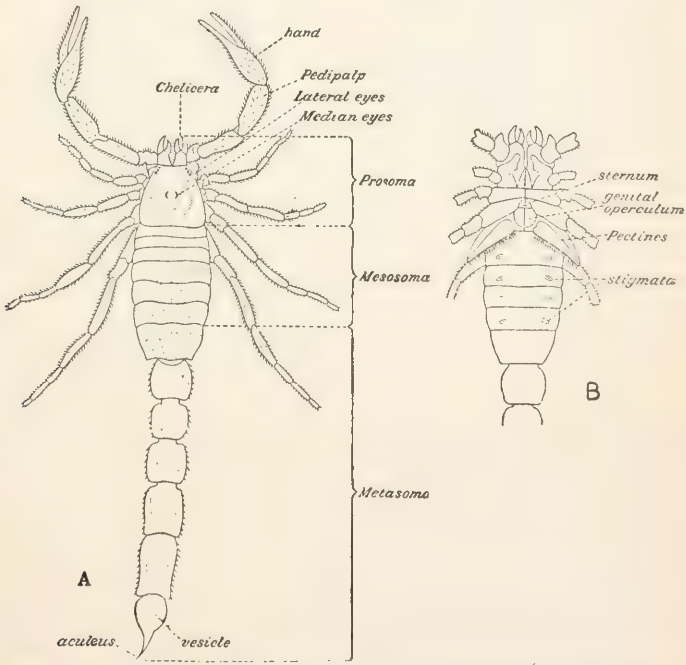

FIG. 65. — Scorpion: **A**, dorsal view; **B**, ventral view. (After Kraepelin.)

sidered a crustacean. The head and thorax form a large horseshoe-shaped piece and the tail is a single long spine. The king crab lives in burrows in the sand and feeds on worms, snails, and other small marine animals.

Characteristics and Classification of Arachnida. — The members of the class *Arachnida* differ markedly from one another,

but agree in several important respects: (1) they have no antennæ; (2) there are no true jaws; (3) the first pair of appendages are nippers, termed cheliceræ; and (4) the body can usu-

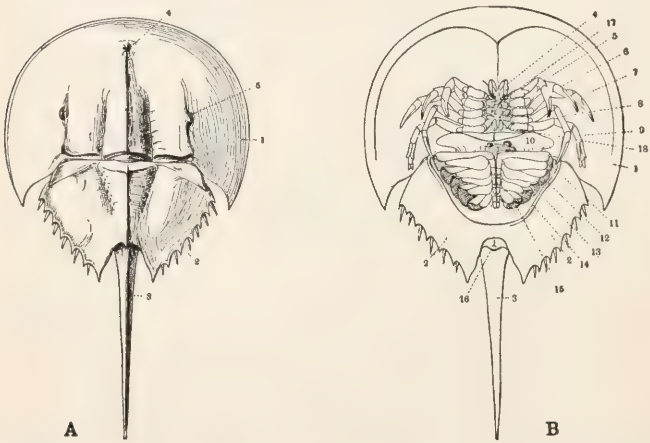

FIG. 66. — The king or horseshoe crab: **A**, dorsal view; **B**, ventral view. (From Shipley and MacBride.)

ally be divided into an anterior part, the cephalothorax, and a posterior part, the abdomen.

Of the twelve orders of *Arachnida* only four need be mentioned, since they contain most of the living species.

Order 1. ARANEIDA. — Spiders.

Order 2. SCORPIONIDEA. — Scorpions.

Order 3. PHALANGIDEA. — Harvestmen, or Daddy Long-legs.

Order 4. ACARINA. — Mites and Ticks.

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CHAPTER XIII

THE RELATIONS OF ARACHNIDS TO MAN

Arachnids are indirectly of importance to man as destroyers of injurious insects and because of their injuries to vegetation, but principally because some of them transmit disease germs from one animal to another, very much as do the house fly, mosquitoes, and certain other insects. (See Chapters VIII, IX, and X.)

Arachnids Destroy Insects. — Spiders, harvestmen, and scorpions are all carnivorous and feed principally upon insects. The number of injurious insects they destroy annually can hardly be estimated, but it must be very large, considering the abundance and voraciousness of spiders.

Spider Silk. — The silk with which spiders build their nests and webs is of excellent quality but difficult to obtain. It must be collected from individual spiders in captivity, and each spider yields only about an ounce. The silk is, nevertheless, sometimes woven into cloth. More important than this, however, is the use of the delicate silk threads as cross hairs in telescopes.

Mites and Ticks. — The mites and ticks are the arachnids that act as parasites on man and domestic animals and sometimes distribute disease germs. Those discussed in the following paragraphs are the tick which causes Texas fever in cattle, the ticks and mites that attack chickens, the mites that cause mange and scab of domestic animals, and the spotted-fever tick, follicle mite, itch mite, and chiggers that parasitize man.

Texas-fever Tick. — The Texas-fever tick transmits a protozoan parasite, named *Piroplasma bigeminum*, from sick cattle to healthy cattle in the South. How serious this disease is may

be judged from the fact that it causes an annual loss of about sixty million dollars to the people living in the fever district.

The relations between the tick and Texas fever were definitely established by Theobald Smith of the Bureau of Animal Industry, U. S. Department of Agriculture, in 1889. The protozoan parasites occur in the blood corpuscles of sick cattle. The ticks suck the blood of these cattle and of course take the parasites into

A B

FIG. 67. — Texas-fever tick.

A, adult female ready to lay its eggs.
B, adult female and egg mass. (After Graybill.)

their alimentary canals. When completely gorged with blood, they drop to the ground ready to lay their eggs. The parasites do not remain in the alimentary canal of the tick, but penetrate into other regions, including the reproductive organs. They are thus present in the eggs laid by the tick.

Each female tick deposits about 2000 eggs on the ground (Fig. 67). The young or "seed ticks," which hatch from these eggs in a few weeks, are parasitized, since the eggs from which they developed contained parasites. They are about $\frac{1}{32}$ of an inch long and have only three pairs of legs. When cattle brush

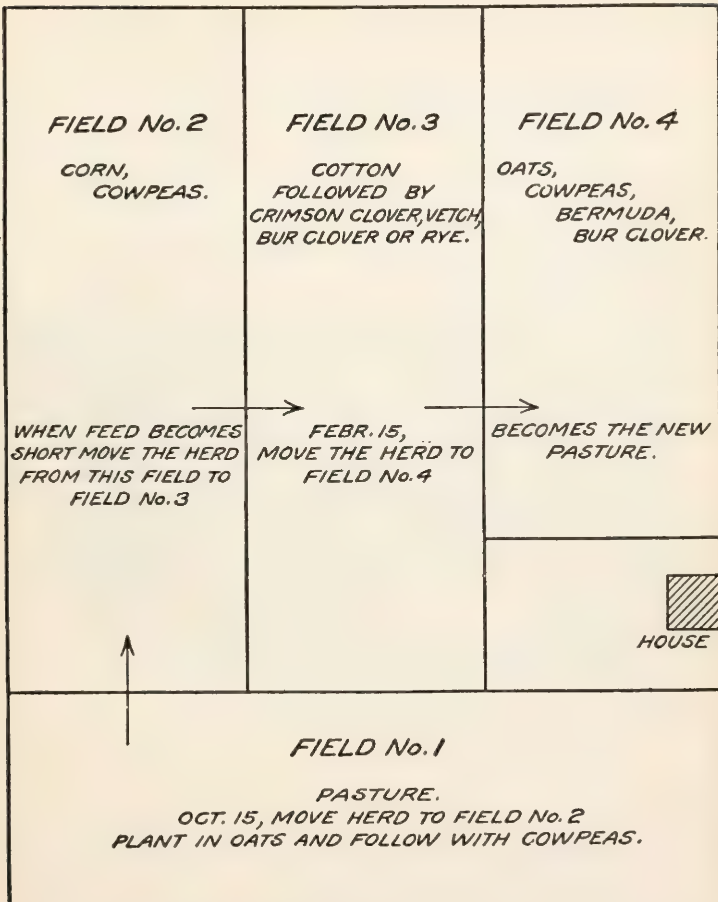

FIG. 68. — Plan which will eradicate the Texas-fever tick from pastures. (After Graybill.)

against the grass blades or weeds to which the young ticks are clinging, the ticks fasten themselves to the bodies of the animals and begin to suck their blood. During this process parasites from the tick's body are transferred to the blood of the cattle.

In this way the disease germs are transmitted from one animal to another.

The control of the Texas-fever tick is very simple. The adult ticks die after laying their eggs, and the young die if they do not gain access to cattle within a few months. A pasture may thus be freed from ticks if left vacant for a few months (Fig. 68). Ticks may also be removed from cattle by dipping the animals in vats containing substances such as crude petroleum or arsenical mixtures which kill the ticks.

Chicken Mites. — Poultry in this country may be attacked by chicken mites and fowl ticks. The mites (Fig. 69, A) are about

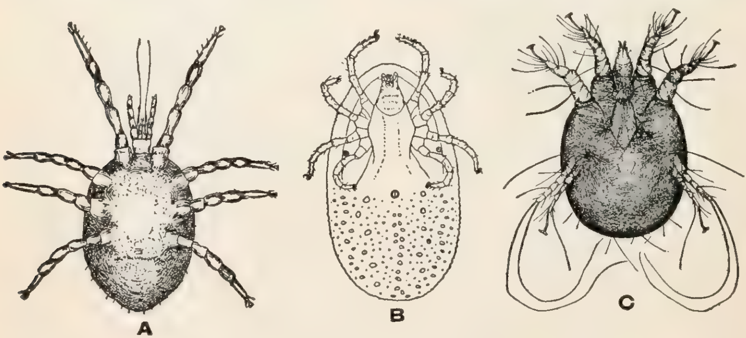

Fig. 69. — Arachnida parasitic on domestic animals.
A, chicken mite; **B**, fowl tick; **C**, scab mite. (After Salmon.)

$\frac{1}{20}$ of an inch long, and red in color when filled with blood, but at other times gray. They suck the blood of the poultry usually at night and hide in crevices during the daytime. A thorough cleansing of the chicken house and an application of a twenty per cent kerosene emulsion will destroy most of the mites. In many parts of the country the chicken mite is considered the most serious poultry pest.

Fowl Ticks. — The fowl ticks (Fig. 69, B) are also a serious pest in the warmer parts of this country. They resemble the chicken mite in shape, but are almost $\frac{1}{3}$ of an inch in length and

of a brownish or bluish-black color. Since they are principally active at night, the fowls may escape them by resting on perches hung from the ceiling with wires or iron rods.

Mites which Cause Scab and Mange. — Certain mites (Fig. 69, C) cause diseases known as scab or mange on sheep, horses, dogs, and other animals. The sheep scab mite is the most important and must be fought instantly wherever sheep are reared. The scabs are caused by the working of the mites in the skin

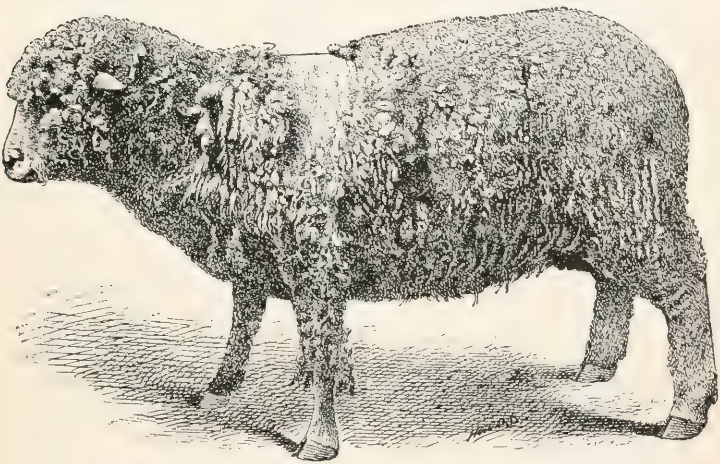

FIG. 70. — A sheep injured by the scab mite. (From Farmers' Bulletin.)

(Fig. 70). These mites may be killed by dipping the sheep in the same manner as that suggested for eradicating the sheep tick (see p. 54).

Itch Mite. — The mites that attack man are comparatively unimportant. The itch mite (Fig. 71, B) is very closely related to the sheep scab mite. It is a minute, whitish mite which lives in the skin and causes intense itching. Cleanliness will prevent infection, and sulphur ointment will eradicate the ticks.

Harvest Mites or Chiggers. — The harvest mites or chiggers (Fig. 71, A) lie in wait in the grass or on shrubs until some luck-

less man or other animal comes along to which it can attach itself. It burrows under the skin, causing itching and sores. Sulphur ointment is the best remedy.

Face Mites. — Face or follicle mites (Fig. 71, C) are rather long, slender arachnids that live in the sweat glands or hair follicles in the skin of man and some other animals. They are supposed to cause the formation of blackheads. That these mites may have something to do with the spread of leprosy and the origin of cancer has also been suggested.

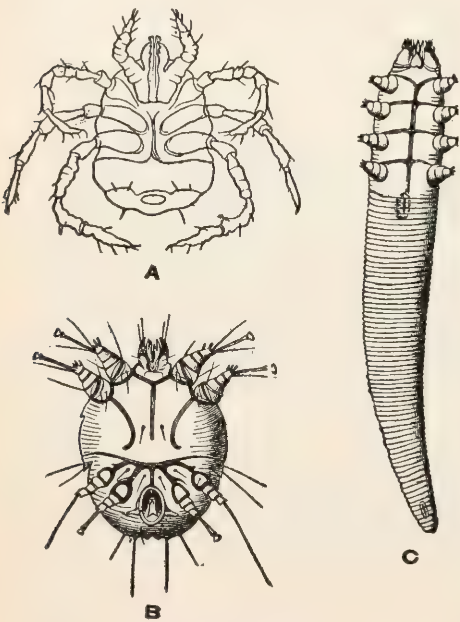

FIG. 71. — Arachnida parasitic on man.

A, harvest mite or chigger; **B**, itch mite; **C**, follicle mite. (From Sedgwick.)

Spotted-fever Tick. — The most serious disease of man that is spread by ticks in this country is spotted fever. This fever occurs in Idaho and Montana and is supposed to be caused by a minute protozoan parasite. The tick transmits these parasites from one animal to another when it bites.

"Red Spiders" on Plants. — In several cases plants are badly injured by mites. The "red spiders" frequently become so numerous in greenhouses, and sometimes outside, that the plants whose juices they suck are seriously damaged. These mites are very resistant to fumigation, but may be destroyed by

spraying the under surface of the leaves with a mixture of one ounce of flowers of sulphur to one gallon of water.

Gall Mites. — Certain mites that resemble the follicle mites in appearance cause a common disease of the pear and apple called pear-leaf blister, and are known as gall mites.

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CHAPTER XIV

THE MYRIAPODA OR CENTIPEDES AND MILLIPEDES

Millipedes. — The myriapods are terrestrial arthropods commonly known as centipedes and millipedes or wireworms. The body of a millipede is subcylindrical, and consists of from about twenty-five to more than one hundred segments, according to the species. Almost every segment bears two pairs of

FIG. 72. — A millipede. (After Koch.)

appendages (Fig. 72), and has probably arisen by the fusion of two segments. The mouth parts are a pair of mandibles and a pair of maxillæ. One pair of antennæ and either simple or aggregated eyes are usually present. The breathing tubes (tracheæ) arise in tufts from pouches which open just in front of the legs.

The millipedes move very slowly, in spite of their numerous legs. Some of them are able to roll themselves into a spiral or ball. They live in dark, moist places and feed principally on vegetable substances.

Centipedes. — The body of a centipede is flattened dorso-ventrally, and consists of from fifteen to over one hundred and fifty segments, which bear each one pair of legs. Centipedes are swift-moving creatures. Many of them live under the bark of logs or under stones (Fig. 73). The poisonous centipedes of

tropical countries may reach a foot in length, and their bite is painful and even dangerous to man.

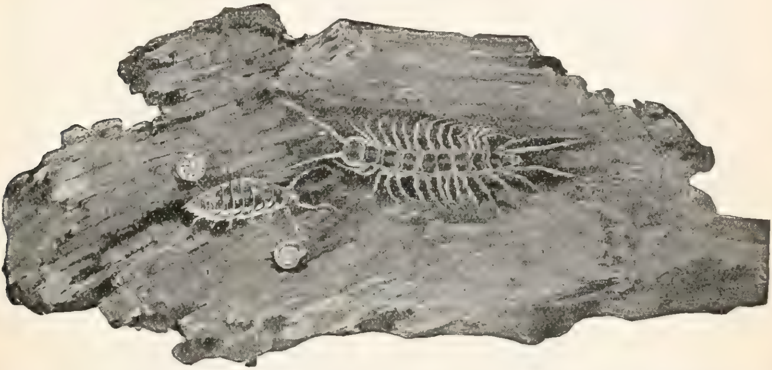

FIG. 73. — A group of animals that live under bark. At the right a centipede. At the left a pill bug, a sow bug, and a snail. (After Davenport.)

Characteristics and Classification. — The chief distinguishing characteristics of the *Myriapoda* are: (1) a distinct head with one pair of tentacles and one pair of mandibles, (2) numerous body segments bearing similar leglike appendages, (3) tracheæ, (4) excretory organs (malpighian tubules) opening into the intestine.

The two principal orders are as follows: —

Order 1. DIPLOPODA. — Millipedes.

Order 2. CHILOPODA. — Centipedes.

CHAPTER XV

THE CRAYFISH

THE crayfish is a typical member of the class *Crustacea* of the phylum *Arthropoda*. It is large enough for study and easily obtained for laboratory use. Crayfishes inhabit fresh-water lakes, ponds, and streams, and although those in one part of the country may differ slightly from those in other localities, the differences are of minor importance, and one description will fit them all. Near the seacoast the lobster is often available for study. Lobsters are larger, but in most other respects resemble the crayfishes.

Habitat. — The crayfish is usually found concealed under rocks or logs at the bottom of ponds and streams. Here it lies with its head toward the entrance to its hiding place. When crawling about or swimming in the open water, its hard shell helps protect it from fish, while its color, which resembles the bottom, tends to make its detection difficult. Crayfishes may be captured easily by hand, with a net, or by fishing for them with a string baited with a piece of meat. They thrive in an aquarium, and their entire life history may be observed in the laboratory. The yearly decrease in the number of lobsters available for food, and the steadily increasing demand for crayfishes, will undoubtedly soon make it worth while to raise the latter for market.

Means of Protection. — The crayfish is protected from its enemies in several ways. The tendency to lie concealed in a crevice during the day and to feed only at night protects it from certain animals like the kingfisher which might otherwise find it.

EXOSKELETON. — The shell or exoskeleton is a sort of armor encasing the body. As in the insect this consists of the substance called chitin, but is made stronger by the addition of calcareous salts. Crayfishes do not thrive well in water that does not contain this mineral matter. From time to time the exoskeleton is shed to allow the growing body to expand. The new shell is at first soft and the animal tries to hide until it becomes hard. The body, like that of the insect, would be very unwieldy if joints were not present (Fig. 74). In these joints the chitin is thin and flexible. The two principal parts of the body differ

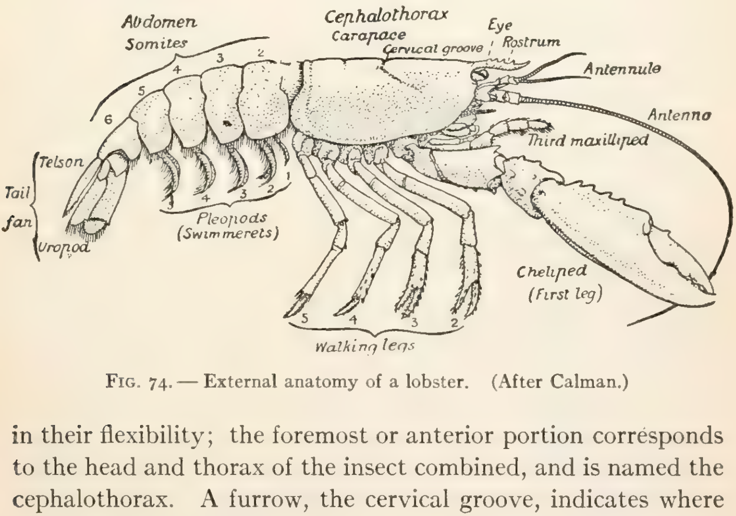

FIG. 74. — External anatomy of a lobster. (After Calman.)

in their flexibility; the foremost or anterior portion corresponds to the head and thorax of the insect combined, and is named the cephalothorax. A furrow, the cervical groove, indicates where these two parts are united.

COLOR. — The color of the crayfish is likewise a means of protection, since it closely matches the bottom of the body of water in which the animal lives. It is in the shell and is formed by green, brown, blue, and red pigments; the color of the body depends upon which color is present in the greatest quantity. When cooked, these pigments all turn red and the whole body becomes " as red as a boiled lobster."

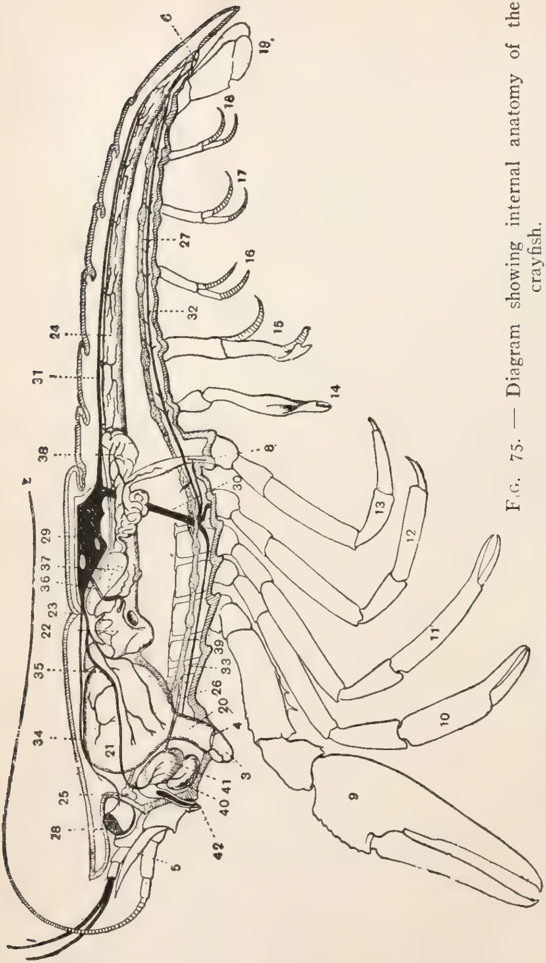

Fig. 75. — Diagram showing internal anatomy of the crayfish.

1, antennule; **2**, antenna; **3**, mandible; **4**, mouth; **5**, exopodite of antenna; **6**, anus; **7**, telson; **8**, opening of vas deferens; **9**, pincher; **10–13**, walking legs; **14–19**, abdominal appendages; **20**, œsophagus; **21**, cardiac chamber of stomach; **22**, pyloric chamber of stomach; **23**, cervical groove; **24**, intestine; **25**, brain; **26**, circumœsophageal connectives; **27**, ventral nerve-cord; **28**, eye; **29**, heart; **30**, sternal artery; **31**, dorsal abdominal artery; **32**, ventral abdominal artery; **33**, ventral thoracic artery; **34**, ophthalmic; **35**, antennary artery; **36**, hepatic artery; **37**, testis; **38**, vas deferens; **39**, internal skeleton; **40**, green gland; **41**, bladder; **42**, external opening of green gland. (From Shipley and MacBride.)

Sensitiveness to Surroundings. — Crayfishes are made aware of the state of their surroundings by their sense organs. When they are hiding, the antennæ are usually protruded and waved back and forth. There are two pairs of these organs; the first

pair, which are called *antennules* (Fig. 75, *1*), consist each of two many-jointed filaments and act as organs of touch, and smell or taste. In the base of each antennule is a cavity containing a calcareous particle; this structure, the statocyst, is an organ of equilibrium, enabling the animal to maintain an upright position in the water.

Each *antenna* of the second pair (Fig. 75, *2*) is a much longer jointed filament, which serves both as a tactile organ and for detecting changes in the chemical constitution of the water.

Enemies may also be located by means of the two compound eyes (Fig. 75, *28*) which are placed on stalks and can be moved in all directions. They resemble in structure those of the insects. The crayfish uses them to locate the insect larvæ, snails, small fish, tadpoles, and other small moving animals that it uses as food.

Locomotion. — Ordinarily the crayfish creeps along upon its stiltlike legs. There are five pairs of these, but the first pair, the pinchers (Fig. 75, *9*), are seldom used to walk with, being held in readiness as weapons of offense and defense. When alarmed, the crayfish walks backwards, and if it becomes necessary for it to escape quickly, it bends its flexible, scoop-shaped abdomen underneath the body and thus swims backward very rapidly in jerks. At the end of the abdomen are two fin-shaped appendages which, like blunt oars, aid in propelling the animal when the abdomen is bent forward under the body. The vital organs of the crayfish are mostly in the cephalothorax, the abdomen being filled with the muscles used in swimming.

Food and Digestion. — The food that the crayfish needs to keep its body going and growing consists by preference of small living animals, but these may be flavored with pieces of plants and other animal and vegetable substances to be found in quiet waters. The large pinchers are used to hold and cut the food into pieces, and the small pinchers on the second and third pairs of legs (Fig. 75, *10* and *11*) carry the pieces to the mouth. Here the six pairs of mouth parts work together, the two pairs of

maxillæ or auxiliary jaws and maxillipeds or foot jaws holding the food while it is being crushed by the true jaws or mandibles (Fig. 75, *3*).

The *food* is not thoroughly ground up, however, until it has passed through the œsophagus (Fig. 75, *20*) into the stomach (Fig. 75, *21*). Here it encounters a number of tooth-like structures which are moved by powerful muscles and form the gastric mill. After being ground up in the gastric mill the food is mixed with digestive juices poured into the stomach by two digestive glands.

Absorption and Circulation. — The digested food is absorbed by the intestinal walls and passes into the blood surrounding the intestine; and the undigested food matter is cast out through the anal opening (Fig. 75, *6*). The blood into which the digested food passes resembles that of insects (see p. 14), but besides transporting food and waste products, it must also carry oxygen and carbon dioxide, as does human blood. There is a well-developed heart (Fig. 75, *29*) which pumps blood into six arteries leading to various parts of the body. As in insects, the body cavity in which the vital organs lie is filled with blood which passes out of the ends of the arteries. Circulation is completed by the entrance of the blood into the heart again.

Respiration. — The crayfish breathes very differently from insects. It is a typical aquatic animal, and its respiratory system consists of gills resembling those of a fish. These gills or branchiæ are attached to the bases of the legs and lie within the branchial chambers. These chambers are formed by an extension of the exoskeleton on each side of the thorax, which protects the delicate filamentous gills from injury. A constant stream of fresh water is forced through these chambers from behind forward by the movements of the oarlike part of the second maxillæ. The gill filaments are supplied with circulating blood which takes up some of the oxygen that is mixed with the water and gives off carbon dioxide to the water.

Reproduction. — Often crayfishes are caught which have

bunches of eggs fastened to the appendages beneath the abdomen. These eggs or " berries " are laid during the month of April, and become attached to the abdominal appendages (the swimmerets) by a sticky secretion. They are carried about and thus protected by the mother until they hatch; then the young still cling to their parent for about two weeks, after which they lead a separate existence. The life of a crayfish extends over a period of about three years. Many crayfishes are destroyed by man, by otters and minks, by fish, and by kingfishers, but the eggs and young are well protected, the continued existence of the race thus being assured.

Fig. 76. — Cotton field damaged by crayfishes after three plantings. (After Fisher.)

Relations to Man. — Crayfishes, as mentioned above, may sometimes be " farmed " in order to supply the demand for food which cannot be satisfied by the lobster industry. At the present time, however, they are of very little value from this standpoint.

The *injuries* done by crayfishes take place in rather restricted localities. Earthen dams, dikes, and fills are sometimes harmed by their burrows, and in the Houston clay lands of Mississippi and Alabama certain areas are so badly infested by burrowing crayfishes that the raising of crops with profit is impossible. The area damaged by these crayfishes is about one thousand square miles. In some places there are over ten thousand of their holes per acre. Cotton and corn plants are cut away by the animals and taken into their burrows to be used as food (Fig. 76).

The most practical and economical means of coping with the crayfish problem is to combine poisoning with killing the crustaceans by mechanical means. During rainy weather and at twilight in the spring after the crayfish become active, the area to be planted with cotton or corn should be visited frequently, and as many as possible of the crayfish killed before seeding time. After the majority have been secured the remaining occupied burrows should be treated with poison, preferably carbon bisulphide (Fisher).

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CHAPTER XVI

CRUSTACEA IN GENERAL

THE crayfish belongs to the order *Decapoda*, so-called because its members possess ten walking legs (five pairs). Most

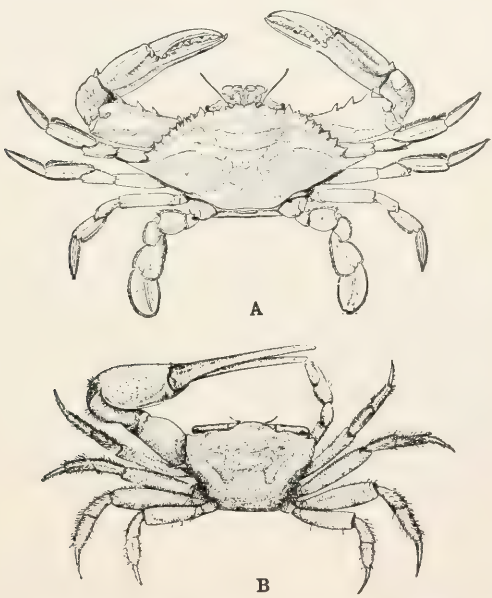

FIG. 77. — **A**, edible or blue crab; **B**, fiddler or soldier crab. (From Paulmier.)

of the larger *Crustacea* are decapods; they not only are the most important so far as our food supply is concerned, but many of them are of great interest because of their peculiar habits and

structural modifications. The lobsters, shrimps, prawns, spider crabs, hermit crabs, edible crabs, and fiddler crabs are all decapods. The rest of the *Crustacea* are for the most part small and inconspicuous. The barnacles have a very remarkable life history. Some of the other species, like the sow bugs, have become terrestrial in habit. Most crustacea live in the sea; a great many species, however, live in fresh water, including the one-eyed *Cyclops*, the water flea, *Daphnia*, and the fairy shrimp, *Branchipus*.

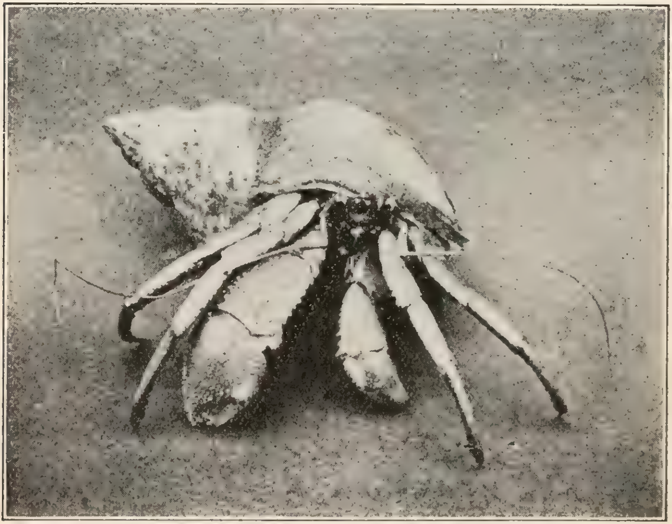

FIG. 78. — Photograph of hermit crab in snail shell. (From Calman.)

Crabs. — The crabs differ from the crayfish in having a very small abdomen which is folded under the large, broad cephalothorax as in the *blue* or *edible crab* (Fig. 77, A). The *spider crabs* are curious-looking creatures with long, stiltlike legs which carry them over the rough sea bottom with ease. One species living in Japan is said to measure twenty feet from tip to tip of the first pair of legs. The *fiddler crabs* (Fig. 77, B) are curious

little animals which run about sideways, moving one of their pinchers, which is larger than the other, in the manner of a fiddle bow.

The *hermit crab* (Fig. 78) is not satisfied with the protection afforded by its exoskeleton, but searches about until it finds an empty snail shell, into which it inserts its abdomen. This protecting shell is then carried about until the hermit crab has outgrown it, when it is cast off and a new and larger one found. Often the shell becomes covered with a colony of polyps. These polyps are transported from place to place by the crab, and in

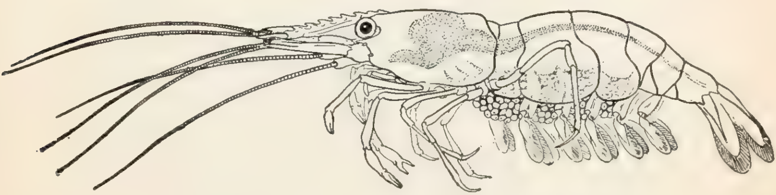

FIG. 79. — A common shrimp. (From Davenport.)

return they pay their fare by stinging any of the crab's enemies that may attack it. Such a relation is similar to that described between the plant lice and the ants (p. 42) and is known as commensalism (*con*, together; *mensa*, table), meaning living at the same table.

Shrimps (Fig. 79) and *prawns* are long-tailed decapods that resemble the crayfish; they are important as a food supply for man.

Barnacles. — The barnacles (Fig. 80) are marine *Crustacea* that were for a long time placed in the same group with the oysters because of their shell. A study of their life history, however, proved them to be *Crustacea*. The young when they hatch from the egg look something like young crayfishes. When they have reached a certain size, they attach themselves to rocks, whales, turtles, or the bottoms of ships, and form a shell about themselves. Here they spend the rest of their lives drawing

water into their shell by movements of their feet and eating the minute plants and animals contained in this water.

Fresh-water Crustacea. — In fresh water, besides the crayfish, one is likely to encounter the fairy shrimp, the water flea, and cyclops. The *fairy shrimp, Branchipus* (Fig. 81, C), is a beautifully colored, almost transparent crustacean, one of the

FIG. 80. — Several oysters to whose shells are attached many barnacles (near the center) and mussels (below and at the sides). (From Bulletin U. S. Fish Com.)

simplest of them all. It is often abundant in the spring in ponds that later dry up. Here it swims slowly about on its back, propelling itself by its leaf-like appendages.

The *water flea, Daphnia* (Fig. 81, B), has a narrow body, resembling a flea in this respect. It is protected by a heavy shell, from the anterior end of which the large antennæ are protruded and moved, serving as swimming organs.

Antennæ are also used as swimming organs by *Cyclops* (Fig. 81, A). Individuals of this little one-eyed creature are present by the million in almost every fresh-water pond. During the summer the female carries a pair of brood pouches full of eggs

with her, one on either side of the abdomen. The single eye of this crustacean suggested the race of mythical giants of Sicily after which it was named.

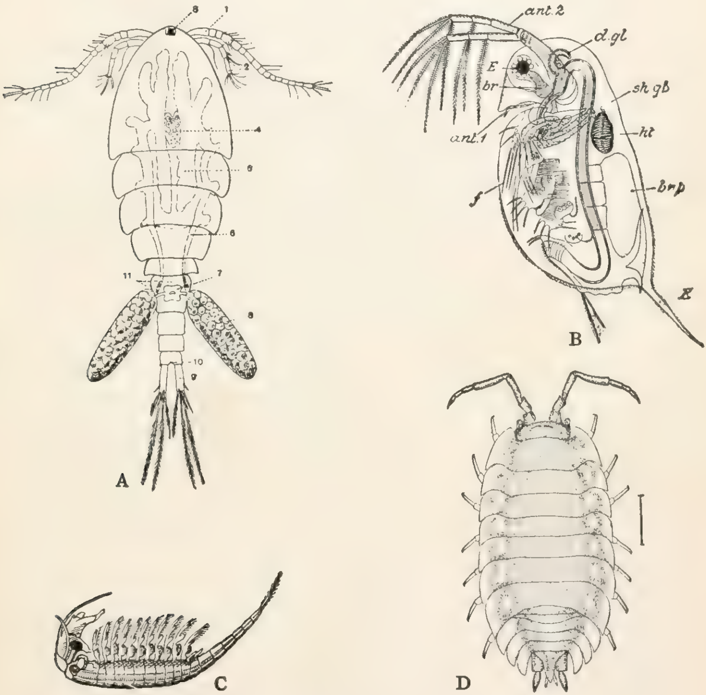

Fig. 81. — Common crustacea.

A, cyclops; **B**, a water flea; **C**, the fairy shrimp; **D**, a sow bug. (After Smith.)

The commonest terrestrial *Crustacea* are the little *pill bugs*, *sow bugs*, or *wood lice* (Fig. 81, D; Fig. 73) which are usually abundant under boards and stones. Their bodies, like that of the cockroach, are much flattened, enabling them to creep into narrow crevices. Although they live on land, they require a moist atmosphere. They feed on decaying vegetable matter.

Relations of Crustacea to Man. — The most obvious relation between the *Crustacea* and man exists in the case of those species that are used for food. A great many different species are utilized in this way in various parts of the world; those most important in this country are crayfishes, lobsters, shrimps, and edible crabs.

The *crayfishes* are not used extensively as food although the difficulty of obtaining lobsters has attracted attention to these smaller relatives, and it is probable that the raising of crayfishes for market will soon become a flourishing industry.

Lobsters have long been used as food. They are especially abundant along the coast of Maine, but occur in lesser numbers at other points on our northeastern coast. Lobsters have been captured so persistently, however, that a great decrease in size has taken place, so that where formerly individuals weighing twenty-five pounds were not rare, now they seldom weigh over two pounds. Many efforts have been made to control the catching of lobsters so as to conserve the supply, but thus far with little success.

The *blue* or *edible crab* (Fig. 77, A) comes next to the lobster as an important article of food for man. It occurs along the Atlantic and Gulf coasts, where, just after shedding its exoskeleton, it is known as the soft-shelled crab. In this condition it is considered more valuable than when the shell is hard.

The *shrimps* (Fig. 79) and *prawns* are smaller than the lobster and crab, and hence of less importance as a food supply for man, though they are captured and eaten in great numbers.

Value as Food for Fish. — Although the *Crustacea* used as food by man in the United States are valued at several millions of dollars annually, still their indirect value as food for fish is probably greater. The smaller *Crustacea* furnish perhaps the principal item in the fish bill of fare. They are extremely abundant everywhere; at one time there may be more than 250,000 in a single cubic yard of lake water and an equal number in an equal amount of sea water. Their effect upon the abun-

dance of mackerel has recently been studied with the following results: The number of fish depends upon the number of *Crustacea* that are available for food. These *Crustacea* feed upon minute plants, mostly diatomes, that float about near the surface of the sea, and their abundance must depend upon the abundance of these plants. The plants require sunlight for their growth and multiplication, so that the amount of sunlight controls the number of plants. Actual observations have shown that a season of bright sunshine is followed by good fishing, and a cloudy one always results in a poor catch of mackerel. The relations here indicated remind one of those pointed out by Darwin between bees and clover (see p. 4).

Injuries Due to Crustacea. — Very few *Crustacea* are injurious to man. The damage done by the crayfish has already been noted (p. 135). Several species make burrows in wood and often do considerable damage to the timbers in piers. Wood that is placed in situations open to attack by little *Crustacea* is commonly treated with creosote.

One species, *Cyclops*, is the means of transmitting the parasitic guinea worm which causes the appearance of dangerous abscesses on the legs of people living in tropical Africa. The young worms that chance to fall into water penetrate the body of the *Cyclops* where they live. Sometimes a parasitized crustacean is swallowed by man, as may easily happen in drinking water from a pond. In the alimentary canal of man the worms are freed, after which they bore their way through his body until they reach the legs, where they produce the abscesses.

Characteristics and Classification. — The *Crustacea* are arthropods most of which live in the water and breathe by means of gills. The body is divided into head, thorax, and abdomen, or the head and thorax may be fused, forming a cephalothorax. The head usually consists of five segments fused together; it bears two pairs of antennæ (feelers), one pair of mandibles (jaws), and two pairs of maxillæ. The thorax bears a variable number of appendages, some of which are usually locomotory. The ab-

dominal segments are generally narrow and more mobile than those of the head and thorax; they bear appendages which are often reduced in size.

A convenient method of classifying the *Crustacea* is to place them in two subclasses.

Subclass I. ENTOMOSTRACA. — Fairy Shrimps, Water Fleas, *Cyclops*, and Barnacles.

Subclass II. MALACOSTRACA. — Pill Bugs, Sow Bugs, Beech Fleas, Shrimps, Crayfish, Lobsters, and Crabs.

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CHAPTER XVII

THE MUSSEL OR CLAM AND OTHER BIVALVES

Habitat. — When we inquire into the details of everyday life of animals, we soon learn that a struggle is all the time taking place between each individual and others of its kind, between it and individuals of other species, and between it and its physical

FIG. 82. — Digging soft-shell clams on a mud-flat. (From Davenport.)

and chemical surroundings. But there are some animals that live in the same general habitat that seem to get along together peacefully. Two examples are the crayfish and the fresh-water mussel or clam. Both inhabit the same ponds or streams and may live within a few inches of each other on the bottom; both must live in water containing calcium carbonate from which part of their shells is built up. Perhaps they live in peace because the crayfish hides under a rock while the mussel plows through the

mud or sand, or because both are so well protected by their shells that neither can injure the other. Most of the mussel-like animals live in the sea; one of these, the long-neck or soft-shell clam, is an important article of food and is dug out of the sands or mud between high-tide and low-tide lines in great numbers and sold in fish markets (Fig. 82). The fresh-water mussel and the long-neck clam differ in certain respects, but their general activities and structure are similar, and either makes good material for study in the laboratory.

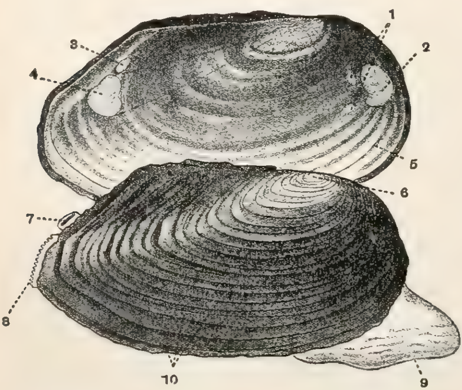

FIG. 83. — The external parts of a mussel. Behind is the inner face of an empty shell.

1, points of insertion of anterior protractor (above) and retractor muscles (below) of the shell; **2**, of anterior adductor muscle; **3**, of posterior protractor of the shell; **4**, of posterior adductor muscle; **5**, lines formed by successive attachment of mantle; **6**, umbo; **7**, dorsal siphon; **8**, ventral siphon; **9**, foot protruded; **10**, lines of growth. (From Shipley and MacBride.)

Locomotion. — If a living mussel is placed on the sandy bottom of a body of water, it will not at first show any signs of life, but if we wait long enough, it will slowly open the two valves of its shell and protrude a wedge-shaped, whitish portion of the body, the foot (Fig. 83, *9*). The foot is gradually extended and forced into the sand, the body is slowly drawn into an upright position, and a large portion of it is soon buried in the bottom. Here the mussel may remain at rest for some time, or it may slowly plow its way through the sand, mud, or gravel by alternately extending its foot and then drawing the rest of the body after it.

The Protective Shell. — The body of the mussel is exceedingly

soft, but it is well protected by the shell. This shell consists of two parts called valves (Fig. 83), and hence mussel-like animals have received the name of bivalves. Each valve is built up of concentric layers of calcium carbonate (Fig. 83, *10*) extracted

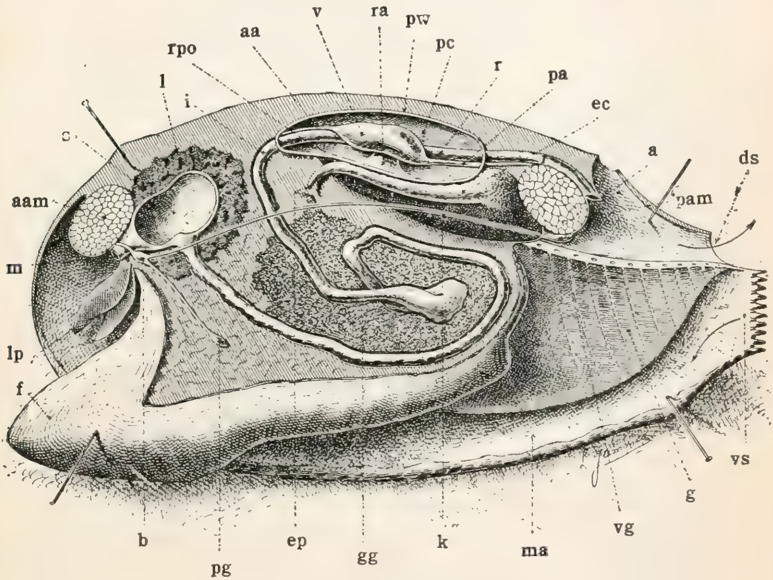

FIG. 84. — Internal organs of a mussel.

a, anus; **aa**, anterior aorta; **aam**, anterior adductor muscle; **b**, brain; **ds**, dorsal siphon; **ec**, excretory canal; **ep**, excretory pore; **f**, foot; **g**, gill; **gg**, genital gland; **i**, intestine; **k**, kidney; **l**, liver; **lp**, labial palp,; **m**, mouth; **ma**, mantle; **pa**, posterior aorta; **pam**, posterior adductor muscle; **pc**, pericardium; **pg**, pedal ganglion; **pw**, pericardial wall; **r**, rectum; **ra**, right auricle; **rpo**, reno-pericardial opening; **s**, stomach; **v**, ventricle; **vg**, visceral ganglion; **vs**, ventral siphon. (After Jammes.)

from the water by the animal and added to the shell by a membrane just under the shell, known as the mantle (Fig. 84, *ma*). The oldest part of the valve is that near the hinge where the lines of growth are shortest; this part is the umbo (Fig. 83, *6*). One cannot tell the age of a mussel by counting the lines of

growth, since there may be more than one growth period during the year.

Structure of the Shell. — If we break a part of the shell, we find that the inner surface produces an iridescent sheen in the light; this is the nacreous layer or mother-of-pearl. Between this layer and the outside is a stratum of calcium carbonate crystals, the prismatic layer; and on the outer surface is a thin, horny layer, the periostracum, which protects the other layers from being dissolved away by the carbonic acid in the water.

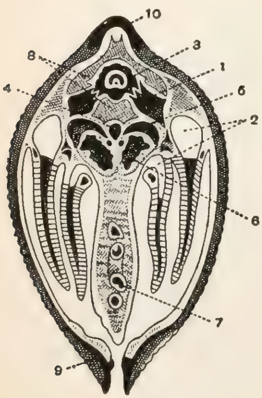

Fig. 85. — Cross section of a mussel.

1, right auricle; **2**, epibranchial chamber; **3**, ventricle; **4**, vena cava; **5**, nonglandular part of kidney; **6**, glandular part of kidney; **7**, intestine in foot; **8**, pericardium; **9**, shell; **10**, ligament of shell. (After Howes.)

Movement of the Valves of the Shell. — The two valves of the shell are held together at the upper, dorsal edges by an elastic, ligamentous hinge (Fig. 85, *10*) and in some species fit together by means of toothlike projections. The elasticity of the hinge tends to force the valves open, but they are held closed or allowed to spring open, to any desired extent by a pair of strong bands of muscles, the adductors, which extend across from one valve to the other, one near the anterior, the other near the posterior edge of the shell (Fig. 84, *aam*, *pam*). When an animal dies, the adductor muscles relax and the valves open. This is why the shells of dead mussels are always open.

Water Current in the Mussel. — When closed or nearly closed, there is within the shell a rather large cavity in which the body lies; this is the mantle cavity (Fig. 85). The mantle cavity communicates with the water surrounding the mussel by means of two tubes or siphons, one above the other, formed by the

mantle at the posterior end and extruding a little from the shell (Fig. 83, *7* and *8*). If a little powdered carmine is placed near the openings of these tubes, it will be drawn into the lower and expelled from the upper one. (See arrows in Figure 84.) This indicates that a current of water is continually entering, passing through the mantle cavity within, and then flowing out again. It is easy to understand from this how the mussel gets its food. Very small particles of animal or vegetable matter floating about in the water are drawn into the mantle cavity through the lower incurrent opening (siphon) and waste matters pass out through the upper excurrent opening (siphon). Oxygen is also taken from this fresh current of water and carbon dioxide passes out through the excurrent siphon.

Principal Parts of the Body. — To study the mechanism which creates these currents one must open up the shell by cutting the large adductor muscles; this is easily accomplished by inserting a sharp knife near either end of the hinge. The parts of the body remind one of the leaves of a book with the valves of the shell representing the covers (Fig. 85). Just within the shell on either side is a thin flap, the two lobes of the mantle that secrete material which forms the shell (Fig. 84, *ma*). Inside of the mantle cavity hang down the thick, muscular foot in the center (Fig. 85, *7*) and a pair of leaf-like gills on either side. Some of the inner organs are inclosed by the foot and the rest are contained in the soft mass above it.

Respiration. — The gills are delicate structures, each consisting of two thin layers of gill filaments connected by longitudinal crosspieces which break it up into tubes (Figs. 84, *g*, and 85). If we cut off a small piece of the gill of a living mussel, an operation that does not cause pain to the animal, and examine it under a compound microscope, we shall find it covered with minute hairlike projections, the cilia, which are waving back and forth. A little powdered carmine placed in the water near the piece of gill will be driven in *one* direction by these cilia. Considering the fact that all the gill filaments are covered with cilia, it is

easy to understand what produces the current of water entering and passing out through the siphons. These cilia always provide a fresh supply of water from which oxygen and food are obtained, thus enabling the sluggish mussel to live successfully without moving about for its food and oxygen. In one respect the mussel and crayfish are similar; both create currents of water which allow them to breathe when resting quietly in one place, but the crayfish must go out after its food and is therefore active, whereas the mussel draws the food to itself and may therefore be as lazy as it pleases.

Sensitiveness to Surroundings. — The mussel has no distinct head, although it possesses near the mouth the nervous ganglia called the brain (Fig. 84, *b*). Its sense organs are also poorly developed. These are all indications that the animal is degenerate. Nevertheless it copes successfully with its enemies and its physical surroundings, which is about as much as can be said of any of the animals, not excluding man.

If the water in which the mussel is living is charged with an injurious chemical substance or if the edges of the siphons are touched, the siphons are drawn in and the shell closed. The animal thus protects itself from injurious substances in the water and from mechanical injury, and the results of the experiments indicate that the edges of the siphons bear sense organs of *touch*. The sense organs which detect chemical changes in the water are supposed to be two yellowish patches, called osphradia, situated just beneath the posterior adductor muscle and hence near where the incoming stream of water enters. No eyes are present, although casting a shadow upon an individual lying in the sun causes a retraction of the siphons and proves it to be sensitive to different light intensities.

Digestion. — The mouth lies near the anterior adductor muscle (Fig. 84, *m*) and is provided with a pair of leaf-like processes on either side, the labial palps (Fig. 84, *lp*). The cilia covering these palps drive food particles into the mouth and down the œsophagus. The digestive apparatus is not very dif-

ferent from that of the crayfish. The food passes through the short œsophagus into the saclike stomach (Fig. 84, *s*), where it is acted upon by digestive juices from the liver (Fig. 84, *l*). That part not absorbed by the walls of the stomach enters the intestine (Fig. 84, *i*) which is coiled about in the foot. The intestine passes through a cavity (the pericardial cavity, Fig. 84, *pc*) just beneath the hinge of the shell and terminates in the anal opening just above the posterior adductor muscle (Fig. 84, *a*).

Circulation. — As in the crayfish, the digested food is absorbed by the walls of the intestine and passes into the blood. There is a heart in the pericardial cavity consisting of a muscular portion, the ventricle (Fig. 84, *v*), which forces the blood through the anterior and posterior aortas (*aa* and *pa*), and a pair of auricles (*ra*) which receive the blood after it has circulated throughout the body, and deliver it to the ventricle. During this circulation, part of the blood passes through the gills, where it receives a fresh supply of oxygen and is relieved of its carbon dioxide, and part enters the walls of the excretory organ, the kidney (*k*), just beneath the pericardial cavity, where the waste materials it bears are excreted. Thus are the functions of digestion, circulation, respiration, and excretion carried on.

Reproduction. — Reproduction in mussels is quite a remarkable process because of the peculiar habits of the young. The adults are either male or female, and the ovaries of the female and testes of the male are situated in the foot (Fig. 84, *gg*). The male fertilizing elements, the spermatozoa, arise in the testes, pass out through the genital opening (*ep*), and are carried from the animal's body in the current of water flowing out of the dorsal siphon. If a female mussel is near, the water containing spermatozoa is drawn into her mantle cavity through the ventral siphon, and the eggs which have dropped from the female genital opening into the gills become fertilized. The developing eggs remain in the gills for a long time, finally changing into a young stage known as a glochidium.

The glochidium has a shell (Fig. 86, A, *sh*) consisting of two valves which are hooked; these may be closed by a muscle (*ad*) when a proper stimulus is applied. A long, sticky thread called the byssus (*by*) extends out from the center of the larva, and bunches of setæ (*s*) are also present.

In the mussel *Anodonta*, the eggs are fertilized usually in August, and the glochidia which develop from them remain in the gills of the mother all winter. In the following spring they are discharged, and if they chance to come in contact with the external parts of a fish, this contact stimulus causes them to

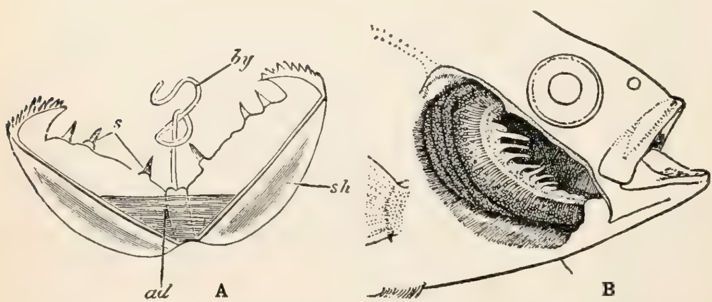

Fig. 86. — **A**. A young mussel or glochidium. **ad**, adductor muscle; **by**, byssus; **s**, setæ; **sh**, shell. (After Balfour.)
B, the gills of a fish in which are embedded many young mussels forming "blackheads." (After Lefevre and Curtis.)

seize hold of the fish's gills by closing the valves of their shell. The glochidium probably chemically stimulates the skin of the fish to grow around it, forming the well-known "worms" or "blackheads" (Fig. 86, B). While thus embedded, the glochidium receives nourishment from the fish and undergoes a stage of development (metamorphosis), during which the foot, muscles, and other parts of the adult are formed. After a parasitic life of from three to twelve weeks, within the tissues of the fish, the young mussel is liberated and takes up a free existence.

One result of the parasitic habit of larval mussels is the disper-

sal of the species through the migrations of the fish. Only in this way can we account for the rapid colonization of certain streams by mussels, since the adult plows its way through the muddy bottom very slowly.

The Oyster. — The oyster is the best-known relative of the mussel principally because of its use as food. Oysters are widely spread, being found on all seacoasts. Those occurring in different localities often belong to different species; those on the Atlantic coast are known by the name *Ostrea virginiana*, and the principal species in Europe as *Ostrea edulis*. In Japan lives a species that sometimes grows to be three feet long.

The adult oyster is unable to move from place to place. It lies on the bottom of the sea, near the coast, attached by its left valve, which is the larger. This attached condition probably explains the absence of the foot in the oyster, since this locomotor organ could be of no use to a stationary animal. The lack of the foot renders the oyster soft and is really responsible for the oyster's edible quality. The mussel, on the other hand, is not relished as a food because of the toughness of its muscular foot. In general structure the oyster differs very little from the mussel.

" Few realize what an enormous business the oyster trade has become in the United States. The value of it is stated to be over thirteen million dollars annually, twenty-five million bushels of oysters being taken from the Chesapeake alone. The edibility of the oyster has been known from early times, for vast heaps of empty oyster-shells, known as kitchen middens, occur in various parts of the world. Some of them are of such size and extent as to warrant the belief that their formation must have required centuries. Shell mounds are found along the coasts of Florida and are of some archæological value. The cultivation of oysters, as recorded by Pliny, dates from the first century B.C.

"The poet Gay's opinion of the first man who ever ate an oyster is expressed thus: —

"'The man had sure a palate cover'd o'er
With brass or steel, that on the rocky shore
First broke the oozy oyster's pearly coat,
And risk'd the living morsel down his throat.'

"The methods employed in oyster farming resemble those of agriculture, in that the bed is prepared, seed is sown, superfluous and foreign growths are weeded out, enemies are driven off, and the crop is harvested at stated seasons. The oyster is ovoviviparous; that is, it retains its eggs until they are partly matured. These are held in the gills and mantle folds until the time of spawning, which begins in May and lasts through the summer months. The larvæ are ejected as ciliated spheres, called spat, and swim freely about for some time, often several days, before finding a resting spot. The oyster grower secures many of the larvæ by placing in their way substances to which they can attach themselves. The American culturist strews his carefully prepared beds with empty oyster-shells, on which the spat settle, and the seed is thus secured; for the spat, once fastened, lose the power of locomotion and become fixed. At the end of a year the shells which hold the young oysters (now about an inch long and called " fry ") are taken up, and the fry are thinned out and replanted, or are sold to other oyster farmers.

" During the period of their growth the oysters are sometimes transplanted several times. At the end of three to five years they have attained marketable size, and the beds are then harvested and prepared for another crop. Some oystermen have several acres of bottom under cultivation. These areas are obtained by purchase or grant from the state, and their limits are as defined as are the fenced-off acres of upland meadows. The business of the oyster culturist is to plant the young oysters and watch their development, keeping the beds thinned that the oysters may not be too crowded for their normal and symmetrical growth, and protecting them from their enemies, of which there are many.

"The principal enemies of the oyster are the starfish and the

predaceous mollusks, *Urosalpinx* and *Nassa*. Whole beds have been known to be destroyed in a single night by the visitations of starfishes, hence a constant watchfulness is required on the part of the oysterman. Policing the oyster farms is another of his cares, for pirates abound, and a bed may be robbed in the night as easily as an orchard may be despoiled of its fruit. Oyster culture is carried on extensively in Long Island Sound, on the coasts of New Jersey and Virginia, and in the Chesapeake Bay. The oysters from certain localities are esteemed more than others, the flavor of the oyster being very dependent upon

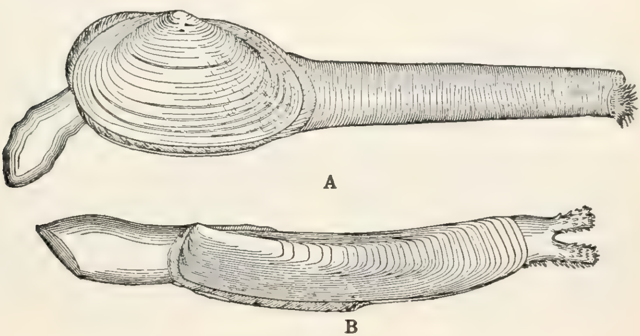

Fig. 87. — **A**, soft-shell clam.
B, razor-shell clam. (From Arnold.)

the purity of the water and on the organisms upon which it feeds. It has been definitely shown that oysters grown in contaminated waters have been the agents of transmitting disease, notably typhoid fever and cholera" (Arnold).

Soft-shell Clam. — Among the other interesting relatives of the fresh-water mussel that one sees at the seacoast are the soft-shell or long-neck clam, the razor-shell clam, the hard-shell clam, and the scallop. The soft-shell clam (Fig. 87, A) lies buried in the mud or sand between tide marks with its long neck, its siphon, stretched up toward the surface. Food is abundant on these mud flats and is obtained, as is that of the

mussel, by the cilia which draw the water loaded with minute particles of animal and vegetable matter into the body through the siphon. The commercial value of the clam is not as great as that of the oyster, but is nevertheless considerable.

Razor-shell Clam. — The razor-shell clam (Fig. 87, B) also lives in burrows in the sand and obtains its food just as the soft-shell clam does. It is a remarkably rapid digger, being able to burrow down into the sand about as fast as one can follow with

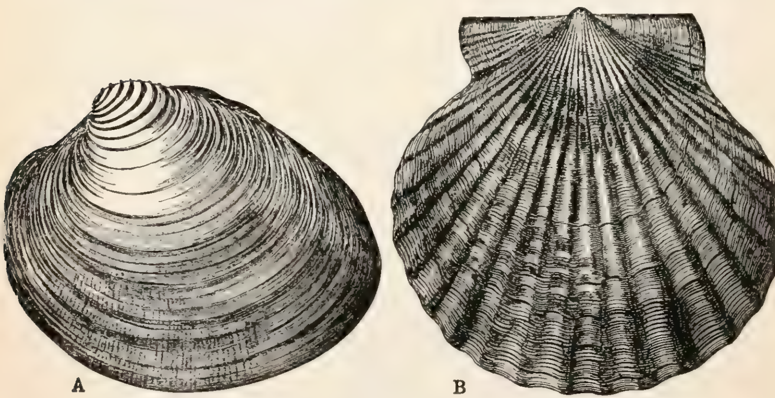

FIG. 88. — **A**, hard-shell or little-neck clam.
B, scallop shell. (From Arnold.)

a spade. The shell is long and slender, hence its popular name, razor-shell clam.

Hard-shell Clam. — The hard-shell clams are very abundant on our eastern coast. One species, *Venus mercenaria* (Fig. 88, A), is commonly known in hotels and restaurants as the "little-neck" clam. It received its specific name (*mercenaria*) because the purple patch on the margin of the shell furnished "wampum," the money used by the Indians.

Scallop. — Scallop shells are among the most beautiful of seashells, and are well known to every one who visits the seacoast (Fig. 88, B). The valves of scallops are rounded and or-

namented with radiating ribs. Near the umbo are two projections, the "ears," characteristic of all the shells of the genus *Pecten* to which the scallops belong.

The outline of *Pecten* has been considerably employed in conventional designs for mural decorations; indeed, the figure of a well-known Mediterranean pecten (*P. jacobius*), found commonly in Palestine, became an emblem of religious significance during the middle ages. Returning crusaders fastened to their garments a specimen of "St. James's shell" as an evidence of the fact that they had been to the Holy Land, and the design of the shell came to be adopted upon many coats of arms and also in the insignia of various orders of devout and adventurous knights of the middle ages (Arnold).

Classification of Mussels and Clams. — The mussels, clams, scallops, and similar bivalves belong to the class *Pelecypoda* of the phylum *Mollusca.* They possess a shell consisting of two valves, a bilobed mantle, and leaf-like gills. There is no head and no rasping organ (radula, see p. 161) in the mouth. They are all aquatic and mostly marine. The four orders into which the class is divided are separated largely on the characteristics of the gills. They are very similar and so need not be given here.

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CHAPTER XVIII

A LAND SNAIL AND OTHER MOLLUSKS

Included with the bivalves in the phylum *Mollusca* are four other classes. Two of these, the *Amphineura* and *Scaphopoda*, are comparatively rare; the third, the *Cephalopoda*, is represented by some very interesting marine species like the octopus and chambered nautilus; and the fourth, the *Gastropoda*, is abundantly represented almost everywhere by the snails and slugs. The activities and structure of snails may best be illustrated by a consideration of a common land snail.

Life on Land. — Mollusks are naturally aquatic animals, and when certain of them forsook the water for a life on land, their habits and structures changed in order to meet the terrestrial conditions. In the first place the evaporation of water from the body had to be retarded. This is accomplished partly by the shell and partly by the layer of viscid substance, the mucus, which covers the skin. However, in spite of these protections from evaporation, land snails can exist only in a moisture-laden atmosphere, becoming active only during damp weather and on dewy nights, when there is no sun to dry up their bodies. When placed in a dry vessel, snails withdraw into their shells and remain inactive until they are moistened; such an experiment may be carried out in any laboratory. In prolonged dry weather the mucus secreted by the edge of the mantle forms a thin membrane, the epiphragm, across the opening of the shell, which prevents desiccation.

Protection. — The Shell. — Snails are protected by their shells not only from evaporation but also from mechanical injury and from many enemies. The shell is coiled about a cen-

tral axis, the columella. The oldest part, as in the bivalves, is the tip where the growth rings are the smallest. It is built large enough to accommodate the entire animal. When properly stimulated, the snail is retracted into its shell by a muscle attached to the columella. The composition of the shell is like that of the mussel, and on account of the necessity of obtaining calcium carbonate with which to build it, snails are only able to live in regions where chalky or limestone soil exists.

Locomotion. — The food of the snail consists of bits of leaves. It must therefore be able to crawl about and must possess the proper sense organs for becoming aware of its surroundings. Snails are notoriously slow-moving creatures, but while they move only at a "snail's pace," still this is rapid enough to enable them to reach their food which is, of course, abundant everywhere.

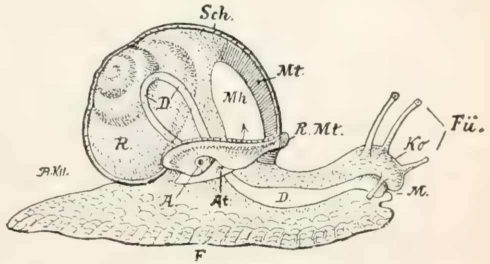


FIG. 89. — Diagram showing the structure of a snail.

A., anus; **At**., respiratory aperture, the entrance to mantle cavity indicated by arrow; **D**., intestine; **F**., foot; **Fü**., tentacles; **Ko**., head; **M**., mouth; **Mh**., mantle cavity; **Mt**., mantle; **R.Mt**., free edge of mantle; **Sch**., shell. (From Schmeil.)

The locomotor organ of the snail is a simple mass of muscle, the foot (Fig. 89, *F*), similar to that of the clam. It is used very differently, however. The foot glides along by means of a series of wavelike contractions which start at the posterior end and move forward. No matter how smooth or rough the surface over which the animal is moving, the speed is always the same. This is explained by the fact that as the snail moves along it secretes near the anterior end of its foot a band of slime or mucus upon which the rest of the foot glides along. Thus the amount of friction is always the same regardless of the roughness of the surface.

Sensitiveness to Surroundings. — The sense organs that make the snail aware of the character of its surroundings, enabling it to find food and escape its enemies, are situated on the head. Unlike the mussel, the snail possesses a very distinct head. The head bears two pairs of tentacles or "horns" (Fig. 89, *Fü.*); the upper, longer tentacles bear each an eye. These eyes, however, are probably not organs of sight, but simply serve to distinguish between lights of different intensities, or since snails are active

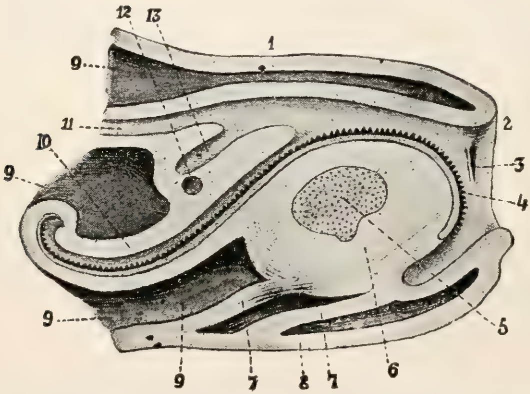


FIG. 90. — The snout of a snail cut vertically and lengthwise to show the mouth and rasping organ.

1, dorsal wall of head; **2**, mouth; **3**, jaw; **4**, *radula;* **5**, cartilage of tongue; **6**, muscular wall of pharynx; **7**, muscles running from pharynx to ventral wall of head; **8**, space in head for withdrawal of tongue; **9**, pocket for radula; **10**, œsophagus; **11**, opening to salivary gland; **12**, fold behind radular pocket. (From Lang.)

at night, may be adapted to dim light. If touched, these tentacles are quickly drawn in, being introverted like the fingers of a glove. Food may be located at some distance, giving us reason to think that snails have a sense of smell; the smaller pair of tentacles is supposed to bear the olfactory organs. A third sort of sense organs, a pair of statocysts, lie in the head and control the equilibration of the animal.

Method of Feeding. — The particles that constitute the

snail's food are rasped from the plants by a thin, filelike band covered with minute backwardly pointed teeth. This organ, the radula (Fig. 90, *4*), is protruded from the mouth and drawn across the plant, thus scraping off very fine particles. A sort of jaw is also present (Fig. 90, *3*) which aids the radula by cutting off pieces of the plant for the radula to work upon.

Respiration. — The terrestrial habit of the snail requires an entirely different breathing apparatus from that of its aquatic relatives, and instead of a mantle cavity filled with water its mantle cavity has become a sort of lung (Fig. 89, *Mh.*). Air is

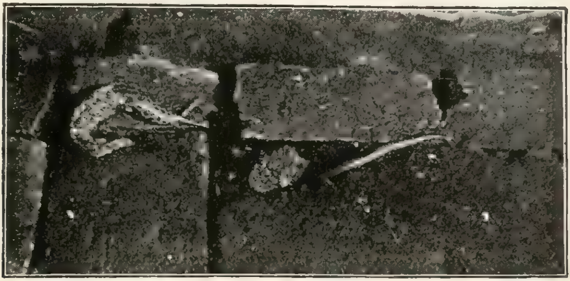


FIG. 91. — Flashlight photograph of earthworm and slug crawling on a pavement at night. (From Davenport.)

taken into and expelled from this cavity, and the exchange of oxygen and carbon dioxide takes place between the air inhaled and the blood in the numerous blood vessels that are present in the lining of the mantle cavity.

Slugs. — Besides the ordinary land snails there are a few terrestrial gastropods that are so peculiar as to deserve special mention; these are the slugs (Fig. 91). Slugs may be found under boards or stones in damp places. They are apparently without a shell, but there is a thin, horny plate embedded in the mantle which is the last remnant of what was no doubt in the slug's ancestors a fully developed shell. Some slugs, especially the introduced species, *Limax maximus*, are a nuisance in greenhouses because of their attacks on plants.

Fresh-water Snails. — The land snails and slugs belong to the order *Pulmonata*, but in this order are also included the fresh-water snails that are so common in ponds and sluggish streams. Pond snails are very easily collected and kept in aquaria. Their habits and structures differ but slightly from their terrestrial relatives. They are not truly aquatic, since they must

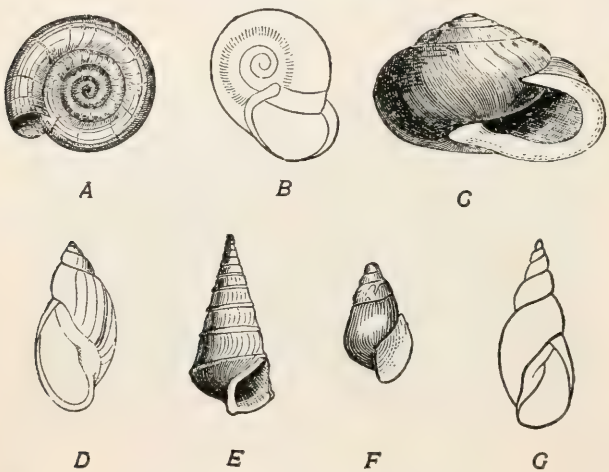


FIG. 92. — Shells of common snails.

A, helicodiscus; **B**, planorbis; **C**, polygyra; **D**, physa; **E**, pleurocera; **F**, goniobasis; **G**, lymnæa. (From various authors.)

come to the surface from time to time to breathe. Often threads of mucus are formed which extend from the bottom to the surface of the water, up which the snails travel when they wish a fresh supply of air. The shells of pond snails are less liable to injury than those that live on land and are correspondingly thinner.

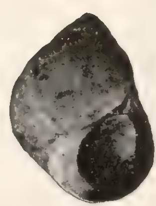
Three common fresh-water snails are *Physa*, *Lymnæa*, and *Planorbis*. *Physa* (Fig. 92, D) lives in ponds and brooks and feeds on vegetable matter. It is a sinistral snail, since if the shell is held so that the opening faces the observer and the spire

points upward, the aperture will be on the left. *Lymnæa* (Fig. 92, G) is a very common pond snail. Its shell is coiled in an opposite direction from that of *Physa* and is called dextral.

A

C

B



D

FIG. 93. — Marine gastropods.

A, sycotypus; **B**, a nudibranch; **C**, the oyster drill; **D**, littorina or periwinkle. (From Davenport.)

Planorbis (Fig. 92, B) differs from *Physa* and *Lymnæa* in having a shell coiled in one plane like a watch spring.

Marine Gastropods. — The majority of the marine gastropods have shells, but many of them do not; some of the latter are

called nudibranchs. The periwinkle (Fig. 93, D) is a very common shelled snail on the North Atlantic seashore. It was introduced from Europe, where in many localities it is used as an article of food by the natives.

The *oyster drill* (Fig. 93, C) and several other marine snails make a practice of boring through the thick shells of oysters and other bivalves with their radulas and taking out the soft body of the victims through the hole.

The term *nudibranch* is applied to certain shell-less marine gastropods. The nudibranchs (Fig. 93, B) resemble the ter-

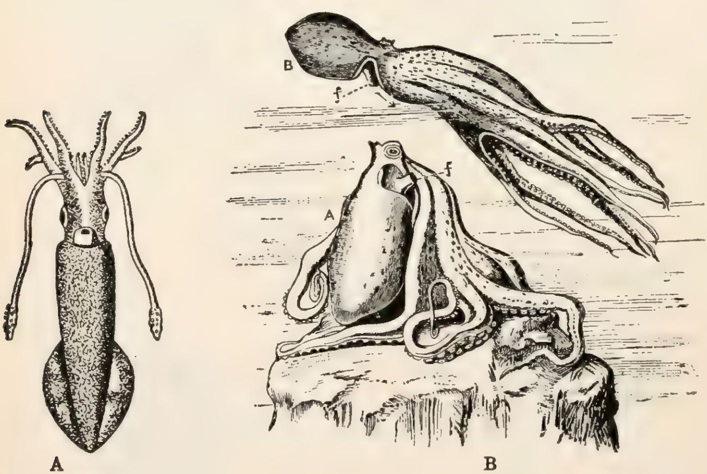


FIG. 94. — **A**, the squid.
B, the octopus; *A*, at rest; *B*, in motion. (After Merculiano.)

restrial slugs; they do not breathe air, however, but take oxygen from the water by means of naked gills, or through the mantle.

The shelled marine *Gastropoda* usually breathe by means of gills. In *Sycotypus* (Fig. 93, A), for example, there is a trough-like extension of the collar, the siphon, which leads a current of water into the mantle cavity where the gill is situated.

Cephalopods. — The cephalopods are all marine mollusks. The commonest species along our eastern coast is the squid (Fig. 94, A). Squids are spindle-shaped animals that swim about freely by means of a pair of fins that wave gently up and down, or propel themselves rapidly in any direction by means of a jet of water forcibly driven from a movable tube, the siphon, situated just beneath the head. Their food consists of small fish, *Crustacea*, and other squids which are captured and held by means of ten tentacles provided with suckers. The squid's

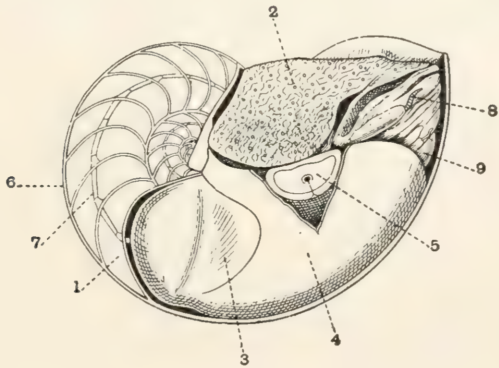


FIG. 95. — The chambered nautilus.

1, last completed chamber of shell; **2**, hood part of foot; **3**, shell muscle; **4**, mantle cut away to expose, **5**, the pinhole eye; **6**, outer wall of shell, partly cut away to show chambers; **7**, siphon; **8**, lobes of foot; **9**, funnel. (After Kerr.)

eyes should be mentioned, for they are very large and resemble somewhat those of human beings.

The relatives of the squid that are perhaps most interesting are the chambered nautilus and the octopus. There are only a few living species belonging to the genus *Nautilus*. The *chambered* or *pearly nautilus*, *Nautilus pompilius* (Fig. 95), lives on the bottom of the sea near certain islands of the South Pacific. The shell is spirally coiled in one plane and is composed of compartments of different sizes, which were occupied by the animal

in successive stages of its growth. The compartments are filled with gas and are connected by a calcareous tube in which is a cylindrical growth of the animal called the siphon (Fig. 95, 7). The gas in the compartments counterbalances the weight of the shell.

The *paper nautilus*, *Argonauta argo*, is a sort of octopus, the female of which secretes a delicate, slightly coiled shell. The *true octopus* or *devilfish* (Fig. 94, B) lives in the Mediterranean Sea and West Indies. It may reach a length of over ten feet and a weight of seventy-five pounds. Devilfishes have been accused of serious attacks on man, but are probably not so bad as generally supposed.

The Relations of Mollusks to Man. — The bivalves are of great economic importance because of their value as food. The oyster is, of course, the most valuable (see p. 153). The other bivalves that are commonly eaten by human beings are the soft-shell clam, razor-shells, hen clams, mussels, and scallops. Certain large snails are considered a delicate article of food, especially by the French. Squids are eaten by some people, particularly the Chinese and Italians.

As Scavengers. — The fresh-water mussels are considered inedible, but their beneficial qualities do not depend upon their food value. They are, first of all, excellent scavengers. All sorts of animal and vegetable particles that pollute the water are drawn into the mantle cavity and thence into the mouth. For this reason, a couple of mussels in a fresh-water aquarium are almost indispensable in keeping the vessel in good condition.

Pearl Buttons. — The shells of mussels are used extensively in the manufacture of pearl buttons, and so freely have these mollusks been captured in the upper Mississippi River for this purpose, and for the pearls they sometimes contain, that the United States Bureau of Fisheries is making strenuous efforts to restock the depleted waters by artificially rearing bivalves. Recently a biological station has been built at Fairport, Iowa, largely with this end in view.

Pearls. — Pearls are interesting and valuable products of bivalves. The most famous pearl fisheries are those of Ceylon. The pearl oysters (really mussels) are taken by the thousand and allowed to decay. Their shells are then washed out and thrown away and any pearls that may be present are picked out of the slimy débris. Pearls are built up around some foreign substance within the shell such as a grain of sand or more probably around the remains of a parasitic worm. The mantle of the mussel secretes the pearl substance in layers, just as the shell is formed. Only a small proportion of the pearls formed by mussels are ever taken, since many of them drop out of the shell and are lost in the bottom and others disappear when the mussels die.

Characteristics and Classification of Mollusks. — Mollusks are soft-bodied animals usually protected by a shell of calcium carbonate. They are unsegmented. The locomotor organ is in most of them a muscular foot. The main part of the body lies in a cavity, the mantle cavity, and is covered by an envelope, the mantle. Three of the five classes contain common and well-known species.

Class 1. Gastropoda. — Snails, Slugs, and Nudibranchs.

Class 2. Pelecypoda. — Bivalves, such as Clams, Mussels, Oysters, and Scallops.

Class 3. Cephalopoda. — Squids, Cuttlefishes, Octopods, and Nautili.

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CHAPTER XIX

THE EARTHWORM AND OTHER SEGMENTED WORMS

Of all the animals that are called worms only a few are true worms; most of them are the larvæ of insects. The true worms are divided into three phyla: (1) the segmented worms or *Annelida*, like the earthworm; (2) the roundworms, or *Nemathelminthes*, like the trichina that sometimes infests pork; and (3) flatworms, or *Platyhelminthes*, like the tapeworm.

Need of Moisture. — The earthworm is the most common member of the phylum *Annelida*, and is abundant almost everywhere if the soil is suitable. The skin of the earthworm is soft and naked, like that of the snail or slug; it is covered with a thin, slimy fluid and requires damp soil or damp atmosphere or else it will dry up. For this reason earthworms are never found in dry, sandy soil, and appear above ground only on dewy nights (Fig. 91), or in cloudy weather, or after a rain. Earthworms are not rained down, as many people suppose, but are rained up out of their burrows.

Burrows. — The body of the earthworm is cylindrical, and long and slender; it is well adapted to the animal's burrowing activities, since the earth offers little resistance to its "vermiform" shape. The burrows are scarcely larger than the diameter of the body and extend, as a rule, only for about two feet underground, although burrows six feet long are sometimes dug.

Locomotion. — In traveling within the burrow as well as on the surface, and in digging the burrows, the movements of the body are similar. The anterior end is extended and the rest of the body drawn up to it. This is accomplished by the muscles in the body wall (Fig. 96, *bw*). An examination of a

cross section of an animal (Fig. 97) will reveal a thick body wall made up principally of two layers of muscles, a layer of circular muscles (*circ. mus*) running around the body just beneath the skin, and a layer of longitudinal muscles (*long. mus*) underneath the circular ones. It is evident that when the circular muscles near the anterior end contract, the body becomes thinner and

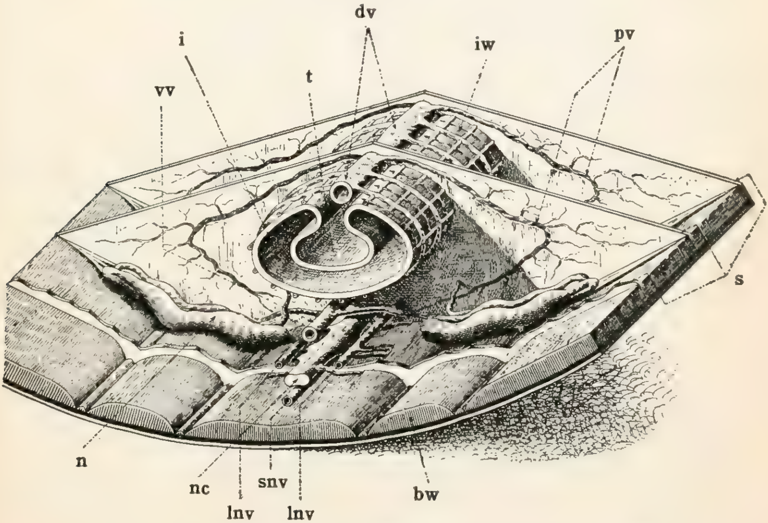

FIG. 96. — Diagram of the internal anatomy of the earthworm.

bw, body wall; **dv**, dorsal vessel; **i**, intestine; **iw**, intestinal wall; **lnv**, lateral neural vessel; **n**, nephridium; **nc**, nerve cord; **pv**, parietal vessels; **s**, septa; **snv**, sub-neural vessel; **t**, typhlosole; **vv**, ventral vessel. (After Jammes.)

therefore extends, and when they relax and the longitudinal muscles contract, the rest of the animal is drawn forward by the shortening caused thereby. The division of the body into rings or segments aids in the activities of these muscular layers.

USE OF BRISTLES IN LOCOMOTION. — The question naturally arises as to what keeps the anterior end of the body from being drawn back by the contraction of the longitudinal muscle. A similar question, why is it so difficult to drag an earthworm

out of its burrow, may be answered at the same time. If a worm be drawn through the fingers from the front backwards, it will feel smooth to the touch, but if drawn from the back forwards, it will feel rough. This is due to the presence of strong,

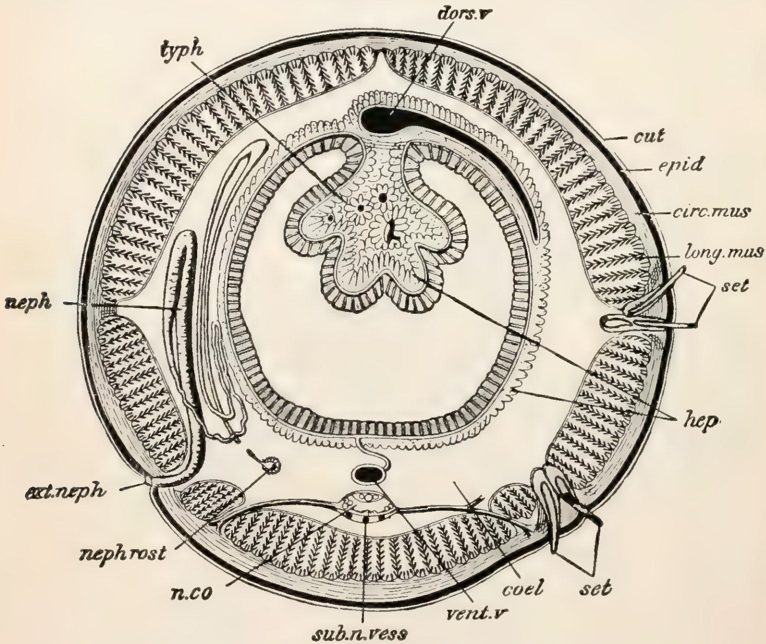

FIG. 97. — Diagram of a cross section of an earthworm.

circ.mus, circular muscle fibers; **coel**, cælom; **dors.v**, dorsal vessel; **epid**, epidermis; **ext.neph**, nephridiopore; **hep**, chlorogogen cells; **long.mus**, longitudinal muscles; **neph**, nephridium; **nephrost**, nephrostome; **n.co**, nerve-cord; **set**, setæ; **sub.n.vess**, subneural vessel; **typh**, typhlosole; **vent.v**, ventral vessel. (From Marshall and Hurst.)

sharp bristles, the setæ, which extend obliquely backward from the sides and under part of the body (Fig. 97, *set*). There are four pairs of these setæ in each segment, and they may be moved by sets of muscles situated just within the body wall. They are moved from behind forward like legs and are of special serv-

ice when used in climbing up in the burrows, since the body of the animal fits its burrow so snugly.

Digging the Burrow. — When digging in soft earth, the worm simply forces its way through by alternate extensions and contractions of the body, but in harder soil it must eat its way through. The body of the worm is like a double tube (Fig. 97), a small one represented by the straight alimentary canal within the larger one, the body wall. The earth that is eaten in digging passes into and directly through the alimentary canal, reaching the surface in the form of castings. The castings of earthworms are the dark heaps of earth so often to be seen on the ground after damp weather.

Food. — Digging in this way not only results in a burrow for the worm, but provides food for it as well, since the soil contains the decaying vegetable matter or humus upon which it feeds, and the animals are careful to make their burrows in soil containing a good supply of humus. Besides this, other food is gathered usually at night when the worms are active. The animals crawl out on the surface, and holding fast to the top of their burrows with their tails, explore the neighborhood for pieces of leaves which they drag into their holes. These leaves when decomposed serve as food for the worms.

Digestion. — The alimentary canal, as usual in higher animals, may be separated into distinct parts, and is accompanied by glands which secrete juices that are discharged into it. The food, after being sucked in by the muscular pharynx, passes into the œsophagus, where it is mixed with a secretion from the calciferous glands; this secretion neutralizes the acids in the food. It then enters the crop, a thin-walled storage place. From the crop it passes into the muscular gizzard, where it is ground up, a process often aided by minute solid particles, like grains of sand, that are swallowed with the food. Next it enters the intestine, where the digestion and absorption chiefly take place (Fig. 96, *i*).

Circulation and Excretion. — A complicated system of blood

vessels carries the blood about the body and with it the digested food (Fig. 96, *dv, vv, pv, lnv, snv*). Waste products pass into the blood as it circulates and are excreted by organs called nephridia (Fig. 96, *n*). Almost every segment contains a pair of these organs. They open into the cavity surrounding the alimentary canal by a ciliated funnel (Fig. 97, *nephrost*) which draws waste matter out of the fluid within the body cavity. The nephridia are well supplied with blood vessels, and in some way extract from the blood circulating through them the excretory substances. These are then expelled from the body through pores, one to each nephridium, which open on either side near the ventral surface of the body (Fig. 97, *ext. neph*).

Respiration. — Oxygen is as necessary for the vital processes of the earthworm as it is for those of higher animals, but there are no well-defined respiratory organs. The oxygen passes through the outer membrane of the body wall into the blood, and carbon dioxide passes out of the blood in the same way.

Sensations. — As might be expected, the earthworm has no well-developed sense organs, like eyes or ears, but nevertheless it exhibits many of the ordinary sensory reactions characteristic of more complex creatures. Thus if a light is thrown upon it at night or if the earth is disturbed near by, it will retreat at once into its burrow. This proves that its sensitiveness to light and to tactile stimuli is sufficient to cause it to seek safety in flight. The senses of taste and smell are probably also present, since a preference for certain kinds of food, such as cabbage leaves, and carrots, is often shown. Minute sense organs have been found at the surface of the body. These seem more abundant at the anterior and posterior ends.

Nervous System. — The nervous system which connects with these sense organs consists of a brain lying above the pharynx and a ventral nerve cord (Fig. 96, *nc*) which is situated between the body wall and the alimentary canal in the median central portion of the body, and extends almost the entire length of the animal. This nerve cord becomes enlarged

in each segment, forming a ganglion from which nerves pass to various parts of the body.

Reproduction. — Earthworms are hermaphroditic animals; that is, every individual is provided with both male and female reproductive organs. When the time for egg laying approaches, the eggs of the worm are inclosed in a cocoon which is secreted by a glandular thickening of the body near the anterior end, the clitellum. They are then fertilized by the spermatozoa from another worm and deposited in the earth, where they hatch into young worms, resembling their parents except in size.

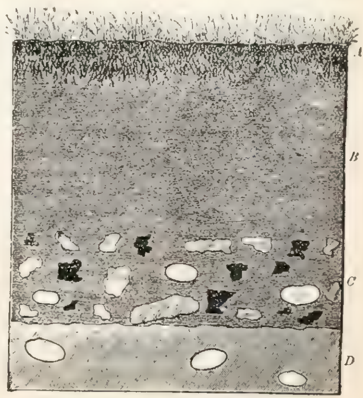

Fig. 98. — Section through the upper stratum of a field showing the work of earthworms.

A and **B**, arable soil thrown up by earthworms; **C**, marl and cinders buried by worm castings; **D**, subsoil not disturbed by the earthworms. (From Schmeil.)

Economic Importance. — Charles Darwin, in his book on the *Formation of Vegetable Mold through the Action of Worms*, has shown, by careful observations extending over a period of forty years, how great is the economic importance of earthworms. One acre of ground may contain over fifty thousand earthworms. The feces of these worms are the little heaps of black earth, called "castings," which strew the ground, being especially noticeable early in the morning. Darwin estimated that more than eighteen tons of earthy castings may be carried to the surface in a single year on one acre of ground, and in twenty years a layer three inches thick would be transferred from the subsoil to the surface. By this means objects are covered up in the course of a few years. Darwin speaks of a stony field which was so changed that "after thirty years (1871) a horse could

gallop over the compact turf from one end of the field to the other, and not strike a single stone with its shoes" (Fig. 98).

The continuous honeycombing of the soil by earthworms also makes the land more porous and insures the better penetration of air and moisture. Furthermore the thorough working over of the surface layers of earth helps to make the soil more fertile.

Segmentation. — Before leaving our study of the earthworm several characteristics should be emphasized. The first of these is segmentation. The most successful animals on the earth, the *Arthropoda*, *Vertebrata*, and *Annelida*, have their bodies built on the segmented plan. The linear row of segments, the somites, or metameres, as they are often called, are very clearly visible in the earthworm, the centipede, and in the abdomen of insects, crayfishes, and scorpions, but are not so obvious in vertebrates. All of these animals, however, have their internal organs segmentally arranged; this is most evident in the case of the nervous system of arthropods and annelids, in the nephridia of the earthworm, and in the backbone of man and other vertebrates which consists of a row of similar bones, the vertebræ.

Of all these animals the earthworm is the best for the demonstration of both external and internal segmentation, since each external ring indicates a single segment and corresponds to a set of internal parts that are repeated in almost every segment. These internal parts are a pair of nephridia, a ganglion of the nerve cord, series of muscle bands, a part of the alimentary canal, and a section of the body cavity separated from the cavity in other segments by transverse partitions, the septa (Fig. 96, *s*).

Body Cavity. — The body cavity is another characteristic of the annelids and higher animals that is worthy of mention; and it is best discussed in connection with the earthworm, where it is very simple. The body-cavity, or cœlom, is filled with a liquid which aids in the distribution of nutritive substances, and bears waste materials for the nephridia to carry from the

body. An animal with thick body walls needs organs for getting rid of excretory substances and for carrying the germ cells (eggs and spermatozoa) out of the body; the nephridia and egg and sperm ducts develop in connection with the cœlom. In insects and other arthropods the body cavity is filled with blood and is not considered a true cœlom.

Leeches. — The best-known segmented worms besides the earthworms are the leeches or "bloodsuckers," a name applied to them because they suck blood from fishes and other aquatic animals and from human beings who wade about or swim in the water. They do not poison people nor inflict any injury except a very slight wound. Leeches are characterized by a flattened, segmented body, and two suckers, one at the posterior end for clinging to its prey and the other at the anterior end, in which the mouth is situated. Many leeches are provided with jaws for biting through the skin; then the blood is sucked into the alimentary canal by means of a muscular pharynx.

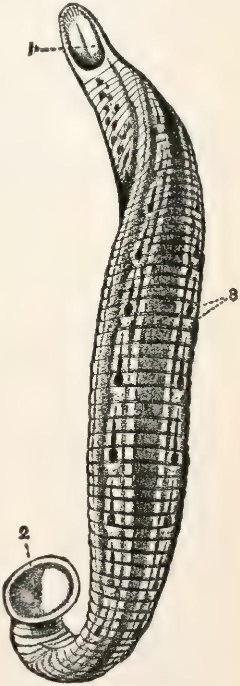

FIG. 99. — The medicinal leech.

1, mouth; **2**, posterior sucker; **3**, sensory papillæ. (From Shipley and MacBride.)

The medicinal leech, *Hirudo medicinalis* (Fig. 99), is only four inches long, but it is capable of great contractions and elongations. It moves along by means of its suckers in loops like a measuring worm or swims through the water by undulating movements. One meal of blood is sufficient to last a leech for as long as a year. Formerly leeches were used by physicians to "bleed" human beings, but this practice has been discontinued.

Fresh-water Segmented Worms. — Smaller and less conspicuous segmented worms are abundant in fresh-water ponds and streams. The tube worm, *Tubifex*, is a reddish colored creature that makes tubes in the mud on the bottom of slow-running brooks. The duckweed worm, *Dero*, frequents the surface of ponds, where it constructs a shelter for itself by fastening together leaves of the duckweed or other plants.

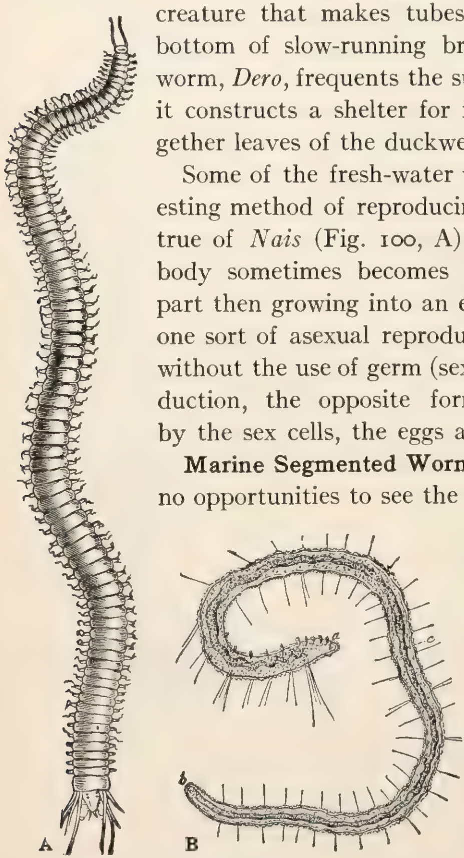

FIG. 100. — **A**, a fresh-water worm, Nais. **B**, a marine worm, Nereis. (After Oersted.)

Some of the fresh-water worms have the interesting method of reproducing by fission. This is true of *Nais* (Fig. 100, A), a little worm whose body sometimes becomes pinched in two, each part then growing into an entire animal. This is one sort of asexual reproduction, or reproduction without the use of germ (sex) cells. Sexual reproduction, the opposite form, is brought about by the sex cells, the eggs and spermatozoa.

Marine Segmented Worms. — Most of us have no opportunities to see the worms that live in the sea, but many of these are very interesting animals. The sandworm or clamworm, *Nereis* (Fig. 100, B), is a common marine annelid that swims freely about in the water by means of pairs of oarlike appendages, one pair on each segment. It also possesses four eyes and a number of tentacles on the head, which bear sense organs of touch and smell. Because of the large number of bristles on its appendages *Nereis* and its relatives are called

Chætopoda or bristle-foot worms. Many of the marine worms live in tubes somewhat like certain fresh-water species. *Serpula*, for example, builds itself a crooked tube of calcium carbonate and fastens it to the rocks near shore. Into this tube the worm quickly withdraws when an enemy threatens.

Characteristics and Classification of the *Annelida*. — Annelids are segmented worms, the body consisting of a linear series of more or less similar parts. Many of the internal organs are also segmentally arranged, notably the blood vessels, excretory organs, and nervous system. Setæ are usually present.

Most of the annelids belong to the two following classes: —

Class 1. CHÆTOPODA. — Annelids with setæ. This class may be subdivided into two subclasses: (1) the *Polychæta*, like *Nereis* (Fig. 100, B), with many setæ and fleshy outgrowths, the parapodia, and (2) the *Oligochæta*, like the earthworm, with few setæ and no parapodia.

Class 2. HIRUDINEA. — Leeches. Annelids without setæ or parapodia, but possessing anterior and posterior suckers.

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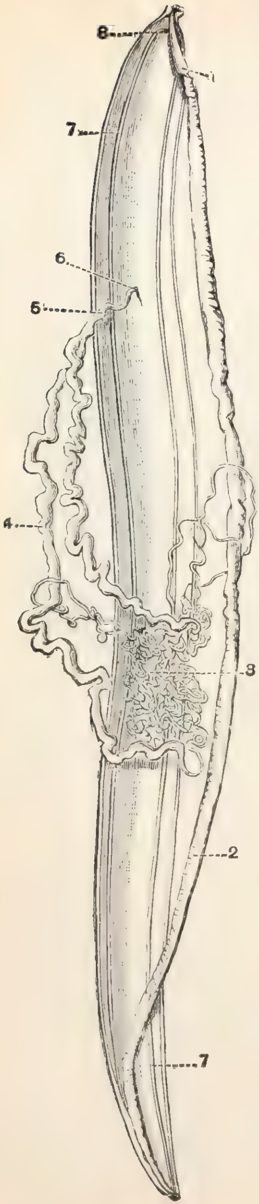
CHAPTER XX

THE ROUNDWORMS

THE unsegmented roundworms (phylum *Nemathelminthes*, Fig. 101) are much more important to man than the segmented annelids, since many of them live as parasites in the bodies of human beings. The roundworms that are most easily obtained are the *vinegar "eels*." These minute worms are abundant in moldy vinegar, and when examined under the microscope, give one a very good idea of what a roundworm looks like. They are not injurious, and no one need be afraid to use vinegar containing them.

"**Horsehair Snakes**." — Sometimes long, slender animals are found wriggling about in watering troughs or in pools of water, and because of their resemblance to a horsehair are known as "horsehair snakes." By many they are thought to be horsehairs that have become alive, but this is, of course, absurd, for horsehairs placed in water will never change into worms. The name *Gordius* has been applied to these animals because they are often tangled up like the Gordian knot which Alexander the Great severed with his sword so long ago. The young spend part of their lives as parasites in the bodies of aquatic insects. When these insects are devoured by other animals, the worms are liberated in their intestines, where they live until full grown and then escape into the water.

Intestinal Parasites. — Several kinds of roundworms may occur in the intestines of human beings, especially children. Some of these, also called threadworms, are from one-fourth to one-half inch long and look like white cotton threads. Others are reddish-white in color and much longer — from four to



twelve inches. As a rule no serious trouble is caused by them. The usual symptoms are disordered digestion, restlessness at night, and grinding of the teeth.

Trichina. — A very serious parasite belonging to this group is the trichina (Fig. 102), which causes the disease of human beings, pigs, and rats called trichinosis. The parasites enter the human body through the eating of inadequately cooked meat from an infected pig. The larvæ soon become mature in the human intestine, and each mature female deposits probably about 10,000 young. These young burrow through the intestinal wall and encyst in the muscular tissue in various parts of the body. As many as 15,000 encysted parasites have been counted in a single gram of muscle.

There is no remedy when one is once parasitized by these worms, but prevention is quite simple; never eat pork that has not been thoroughly cooked. Pigs acquire the disease by eating offal or infested rats.

Hookworm. — Another serious parasite of man is the hookworm (Fig.

FIG. 101. — Anatomy of a female roundworm, Ascaris.

1, pharynx; **2**, intestine; **3**, ovary; **4**, uterus; **5**, vagina; **6**, genital pore; **7**, excretory tube; **8**, excretory pore. (From Shipley and MacBride.)

103, D). One of the most recent discoveries with regard to this parasite is that the shiftlessness of the "poor whites" of the South is to a certain degree the result of its attack. The larvæ of the hookworm develop in moist earth and usually find their way into the bodies of human beings by boring through the skin of the foot. The hookworm is prevalent in many localities where the people go barefoot. The larval hookworms enter the veins and pass to the heart; from the heart they reach the lungs,

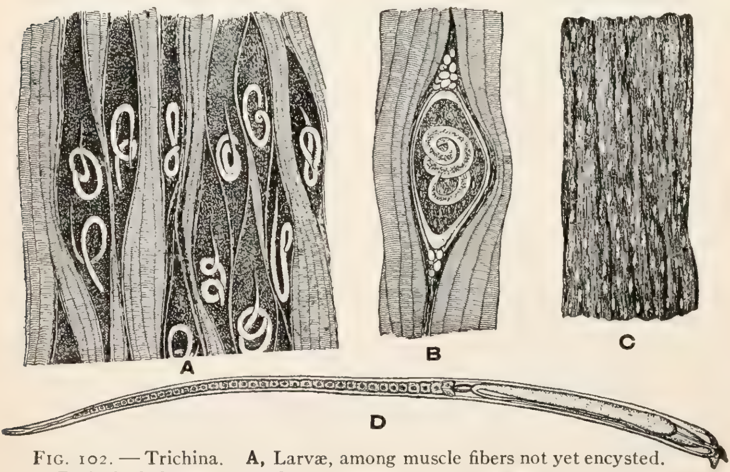


FIG. 102. — Trichina. **A,** Larvæ, among muscle fibers not yet encysted. **B,** A single larva encysted. **C,** Piece of pork, natural size, containing many encysted worms. **D,** Adult trichina, much enlarged. (After Leuckart.)

where they make their way through the air passages into the windpipe and thence into the intestine. To the walls of the intestine the adults attach themselves and feed upon the blood of their host. When the intestinal wall is punctured, a small amount of poison is poured into the wound by the worm. This poison prevents the blood from coagulating, and therefore results in a considerable loss of blood, even after the worm has left the wound.

The victims of the hookworm are anæmic, and also subject to tuberculosis because of the injury to the lungs. It is

estimated that 2,000,000 persons are afflicted by this parasite. The hookworm disease can be cured by thymol (which causes the worm to loosen its hold) followed by Epsom salts. The most important preventive measure is the disposing of human feces in rural districts, mines, brickyards, etc., in such a manner as to avoid pollution of the soil, thus giving the eggs of the parasites contained in the feces of infested human beings no opportunity to hatch and develop to the infectious larval stage.

Elephantiasis. — Another injurious species is *Filaria bancrofti*, a parasite in the blood of man. The larvæ of this species are about $\frac{1}{100}$ of an inch long. During the daytime they live in the lungs and larger arteries, but at night they migrate to the blood vessels in the skin. Mosquitoes, which are active at night, suck up these larvæ with the blood of the infected person. The larvæ develop in the mosquito's body, becoming about one twentieth of an inch long, make their way into the mouth parts of the insect, and enter the blood of the mosquito's next victim. From the blood they enter the lymphatics and may cause serious disturbances, probably by obstructing the lymph passages. This results in a disease called elephantiasis. The limbs or other regions of the body swell up to an enormous size, but there is very little pain. No successful treatment has yet been discovered, and the results are often fatal. It is said that from 30 per cent to 40 per cent of the natives of certain South Sea islands are more or less seriously afflicted. The parasitic guinea worm has already been described as a parasite of the crustacean, *Cyclops* (see p. 140).

Other Roundworms. — Parasitic roundworms also attack other animals and plants. One of them, *Syngamus* (Fig. 103, C), causes the disease known as gapes in poultry and game birds. The birds swallow the young worms, which soon become mature in the windpipe. The stomach worm of sheep (Fig. 103, B) is the most important worm that parasitizes these animals. It lives in the fourth stomach of sheep and goats and causes the death of many animals, especially lambs. The nodular worm of

sheep (Fig. 103, A) causes the production of numerous small nodules in the walls of the large intestines. These are sometimes mistaken by government inspectors in slaughterhouses as evidences of tuberculosis. Dogs are frequently attacked by worms of the genus *Ascaris* to which the parasitic roundworm of man also belongs. Breeders of fancy dogs lose many valuable animals because of the attacks of these worms. Other round-

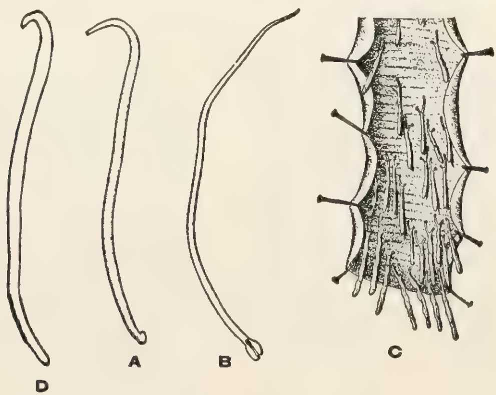


FIG. 103. — Parasitic roundworms.

A, nodular worm of sheep; **B**, stomach worm of sheep; **C**, worms that cause gapes in poultry; **D**, hookworm.

worms live in the soil and cause growths called galls to form on the roots of plants.

Characteristics and Classification. — The roundworms or threadworms belong to the phylum *Nemathelminthes*. They are usually long and slender and more or less cylindrical. They are unsegmented, both externally and internally, and hence easily distinguished from the annelids or segmented worms. Many roundworms are parasitic in habit, but others live in water or decaying vegetable and animal substances.

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CHAPTER XXI

THE FLATWORMS

THE flatworms are, like the roundworms, chiefly parasitic, and hence of the utmost importance to man. The fresh-water flatworm, *Planaria*, will be chosen first for study, since it is very abundant, can easily be studied in the laboratory, and is comparatively simple. Planarians and leeches are often confused, since both are frequently found clinging to the underside of logs or stones in ponds and streams. They can be distinguished quite readily, however, since the leech is segmented and has suckers, whereas the flatworm is unsegmented and devoid of suckers.

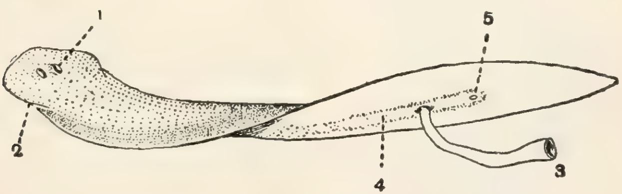

FIG. 104. — A fresh-water flatworm, planaria.

1, eye: **2**, side of head; **3**, proboscis; **4**, pharynx sheath; **5**, genital pore. (From Shipley and MacBride.)

Planaria. — The shape of *Planaria* is indicated in Figure 104. The animal moves along over stones or other objects by means of muscular contractions or swims through the water with the aid of the cilia which cover it. At the anterior end are two eyespots (Fig. 104, *1*), sensitive to light, and two sensory pits, one on either side of the head (*2*), situated in earlike projections On the ventral surface a trifle back of the middle is the mouth opening (*3*).

Because of the great amount of coloring matter in its body the internal organs are difficult to make out. They may be described briefly with the aid of a diagram (Fig. 105). A muscular pharynx can be extended from the mouth as a proboscis (Fig. 104, *3*); this facilitates the capture of food. The food is digested in the intestinal trunks (Fig. 105, i_1, i_2, i_3) by secretions from their walls and is absorbed by the walls. Since branches from these penetrate all parts of the body, no circulatory system is necessary to carry nutriment from one place to another. The excretory matter is collected and carried to the outside by a pair of longitudinal, much-coiled tubes, one on each side of the body; these are connected near the anterior end by a transverse tube, and then open to the exterior in two small pores on the dorsal surface.

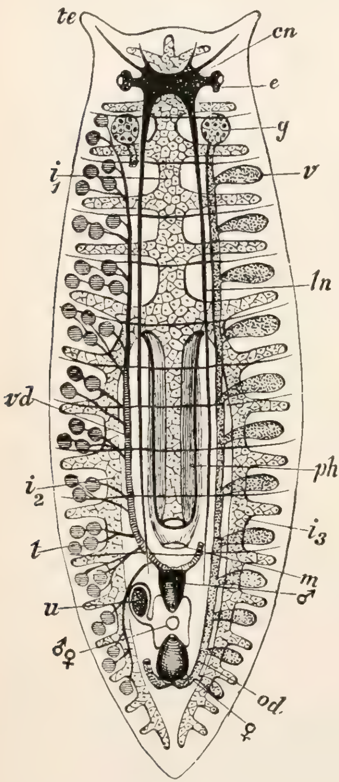

Fig. 105. — Anatomy of a flatworm.

cn, brain; **e**, eye; **g**, ovary; **i₁**, **i₂**, **i₃**, branches of intestine; **ln**, lateral nerve; **m**, mouth; **od**, oviduct; **ph**, pharynx; **t**, testis; **u**, uterus; **v**, yolk glands; **vd**, vas deferens; ♂, penis; ♀, vagina; ♂♀, common genital pore. (After V. Graff.)

Planaria possesses a well-developed nervous system, consisting of a bilobed mass just beneath the eyespots called the brain (Fig. 105, *cn*), and two lateral longitudinal nerve cords (*ln*), connected by transverse nerves. From the brain, nerves pass to various parts of the anterior end of the body, imparting to this region a highlv

sensitive nature. Reproduction is by fission, as in *Nais* (p. 176), or by the sexual method, and each individual possesses both male and female organs, *i.e.* is hermaphroditic. The reproductive organs may be located easily in Figure 105.

Regeneration. — Planarians show remarkable powers of regeneration. If an individual is cut in two (Fig. 106, A), the anterior end will generate a new tail (B, B¹), while the posterior part develops a new head (C, C¹). A cross-piece (D) will generate both a head at the anterior end, and a new tail at the posterior end (D–D⁴). The head alone of a planarian will grow into an entire animal (E–E³). Pieces cut from various parts of the body will also regenerate completely. No difficulty is experienced in grafting pieces from one animal upon another, and many curious monsters have been produced in this way.

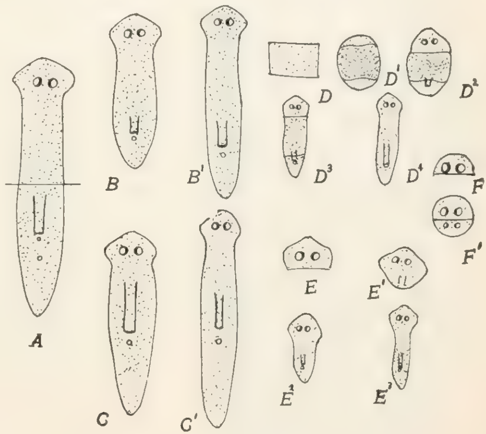

Fig. 106. — Regeneration of planaria.

A, normal worm; **B**, **B**¹, regeneration of anterior half; **C**, **C**¹, regeneration of posterior half; **D**, cross-piece of worm; **D**¹, **D**², **D**³, **D**⁴, regeneration of same; **E**, old head; **E**¹, **E**², **E**³, regeneration of same; **F**, **F**¹, regeneration of new head on posterior end of old head. (From Morgan.)

The power to renew lost parts by regeneration is of great importance to these animals, since their soft bodies are often injured by the rocks in the streams among which they live.

Parasitic Flatworms. — Besides *Planaria* and other free-living flatworms that belong to the class *Turbellaria*, there are two classes of parasitic flatworms, the *Trematoda* or flukes and the *Cestoda* or tapeworms.

The Liver Fluke. — The liver fluke is a flatworm which lives as an adult in the bile ducts of the liver of sheep, cows, pigs, etc., and is occasionally found in man. Figure 107 shows the shape and most of the anatomical features of a mature worm. The mouth (*O*) is situated at the anterior end and lies in the middle of a muscular disk, the anterior sucker. A short distance back of the mouth is the ventral sucker (*S*); it serves as an organ of attachment. Between the mouth and the ventral sucker is the genital opening through which the eggs pass to the exterior. The excretory pore lies at the extreme posterior end of the body.

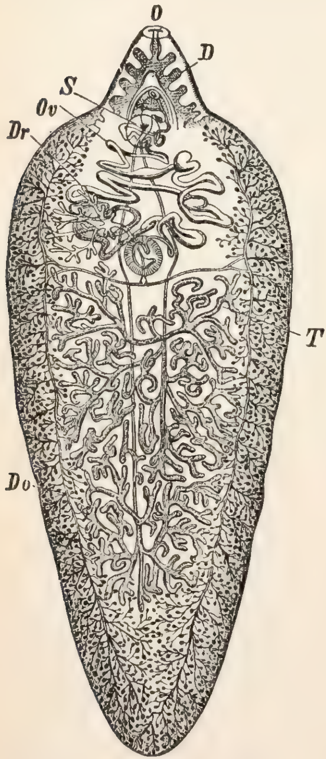

FIG. 107. — Anatomy of the liver fluke.

D, anterior part of intestine (posterior part not shown); **Do**, yolk-glands; **Dr**, ovary; **O**, mouth; **Ov**, uterus; **S**, sucker; **T**, testes. (After Sommer.)

The alimentary canal resembles that of *Planaria*, and the reproductive organs, as the figure shows, are very complex. One liver fluke may produce as many as five hundred thousand eggs, and since the liver of a single sheep may contain more than two hundred adult flukes, there may be one hundred million eggs formed in one parasitized animal. The eggs pass through the bile ducts of the sheep into its intestine, and finally are carried out of the sheep's body with the feces. Those eggs that encounter water and are kept at a temperature of about 75° F. continue to develop, producing a ciliated larva (Fig. 108, **a**), which es-

capes through one end of the eggshell and swims about. This larva is called a miracidium. It swims about until it encounters a certain fresh-water snail, but if no snail is found within eight hours, the larva dies.

When a snail is reached, the larva bores its way into the soft parts of the body. Here in about two weeks it changes into a

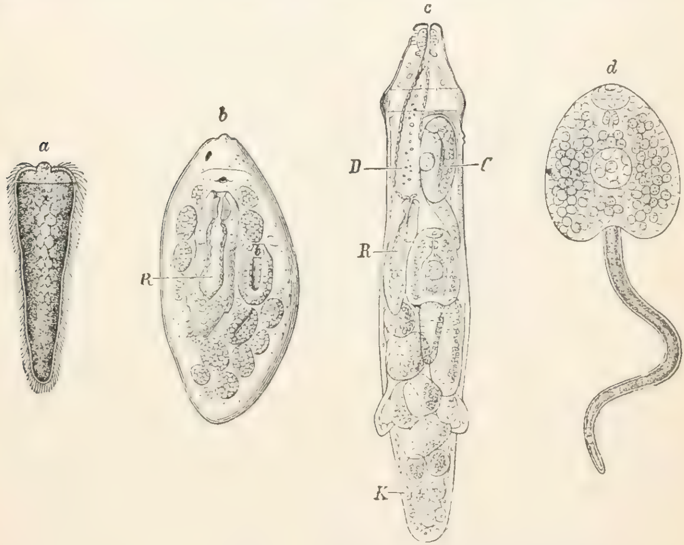

FIG. 108. — Stages in the life-history of the liver fluke.

a, miracidium (ciliated embryo); **b**, sporocyst containing rediæ (**R**); **c**, a redia; **C**, cercaria; **D**, gut; **K**, germ-cells; **R**, redia; **d**, cercaria. (From Sedgwick.)

saclike sporocyst (Fig. 108, **b**). Each germ cell within the sporocyst develops into a second kind of larva, called a redia (Fig. 108, **b**, *R*; **c**). The rediæ soon break through the wall of the sporocyst and by means of germ cells (Fig. 108, **c**, *K*) usually give rise to one or more generations of daughter rediæ (Fig. 108, **c**, *R*), after which they produce a third kind of larva known as a cercaria (Fig. 108, **c**, *C*). The cercariæ (Fig. 108, **d**) leave the body of the snail, swim about in the water for a time, and

then encyst on a leaf or blade of grass. If the leaf or grass is eaten by a sheep, the cercariæ escape from their cyst wall and make their way from the sheep's alimentary canal to the bile ducts, where they develop into mature flukes in about six weeks.

The great number of eggs produced by a single fluke is necessary, because the majority of the larvæ do not find the particular kind of snail, and the cercariæ to which the successful larvæ give rise have little chance of being devoured by a sheep. The generations within the snail, of course, increase the number of larvæ which may develop from a single egg. This complicated life history should also be looked upon as enabling the fluke to gain access to new hosts. The liver fluke is not so prevalent in the sheep of this country as in those of Europe.

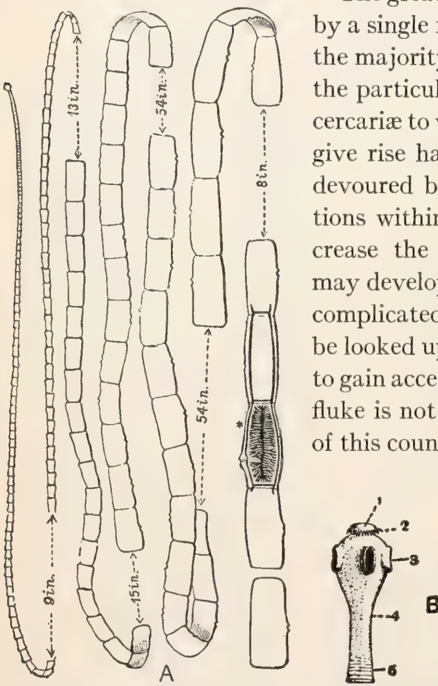

FIG. 109. — **A**, tapeworm. The lengths of parts omitted in the figure are indicated. **B**, head or scolex of tapeworm. (From Shipley and MacBride.)

The Tapeworm. — The tapeworm, *Tænia solium*, is a common parasite which lives as an adult in the alimentary canal of man. A nearly related species, *Tænia saginata*, is also a parasite of man. *Tænia*, as shown in Figure 109, is a long flatworm consisting of a knoblike head, the scolex (Fig. 109, B), and a great number of similar parts, the proglottides, arranged in a linear series. The animal clings to the wall of the alimentary canal by means of hooks (Fig. 109, B, *2*) and suckers (*3*) on the scolex. Behind the scolex is a short neck (*4*) followed by a

string of proglottides which gradually increase in size from the anterior to the posterior end. The worm may reach a length of ten feet and contain eight or nine hundred proglottides. Since the proglottides are budded off from the neck (Fig. 109, B, 5), those at the posterior end are the oldest.

The anatomy of the tapeworm is adapted to its parasitic habits. There is no alimentary canal, the digested food of the

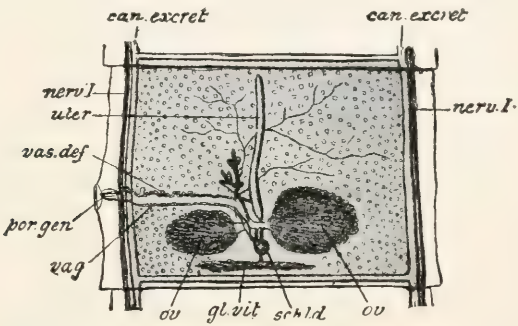

FIG. 110. — A proglottid of a tapeworm.

can.excret, longitudinal excretory canals with transverse connecting vessels; **gl.vit**, vitelline or yolk-glands; **nerv.l**, longitudinal nerves; **ov**, **ov**, ovaries; **por.gen**, genital pore; **schld**, shell-glands; **uter**, uterus; **vag**, vagina; **vas.def**, vas deferens. The numerous, small, round bodies are the lobes of the testes. (After Leuckart.)

host being absorbed through the body wall. A mature proglottid is almost completely filled with reproductive organs; these are shown in Figure 110.

The eggs of *Tænia solium* develop into six-hooked embryos (Fig. 111, **a**) while still within the proglottis. If they are then eaten by a pig, they escape from their envelopes (**b**) and bore their way through the walls of the alimentary canal into the voluntary muscles, where they form cysts (**c**). A head is developed from the cyst wall (**d**) and then becomes everted (**e**). The larva is known as a bladder worm or cysticercus at this stage. If insufficiently cooked pork containing cysticerci is eaten by man, the bladder is thrown off, the head becomes fas-

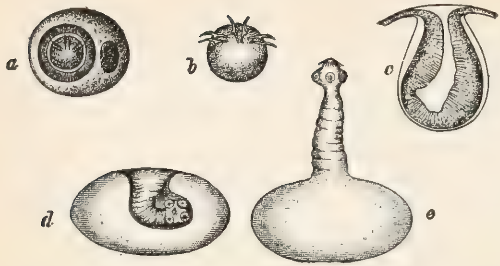

FIG. 111. — Stages in the development of a tapeworm.

a, egg with embryo; **b**, free embryo; **c**, rudiment of the head as a hollow papilla on wall of vesicle; **d**, bladder-worm (cysticercus) with retracted head; **e**, the same with protruded head. (From Sedgwick.)

tened to the wall of the intestine, and a series of proglottides is developed.

The adult tapeworms found in the alimentary canal of man and other animals interfere seriously with the digestion and absorption of food, but the larvæ are more dangerous. For example, the larvæ of the tapeworm, *Tænia echinococcus* (Fig. 112, A), which lives

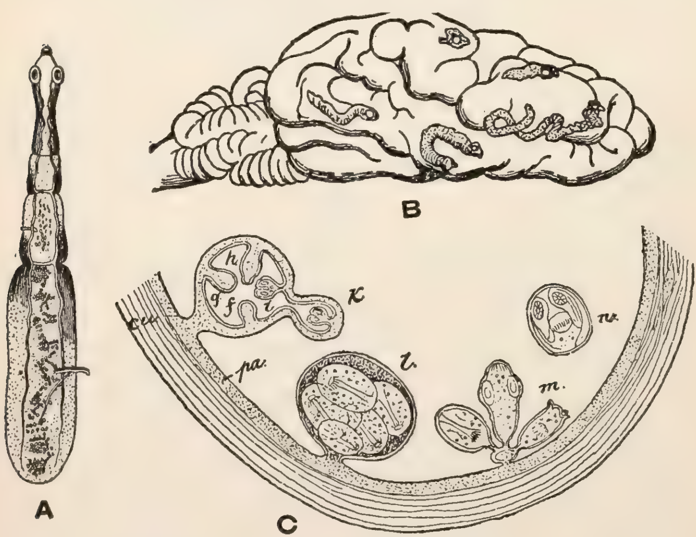

FIG. 112. — **A**, an adult hydatid tapeworm.
B, brain of a lamb infested with young gid bladder worms.
C, diagram of part of an hydatid. (After Blanchard.)

as an adult in the dog, may form large vesicles in man, known to physicians as hydatides (Fig. 112, C), which may break with serious or even fatal results. The organism which causes "gid" or "staggers" in sheep (Fig. 112, B) is the larva of the dog tapeworm, *Tænia cœnurus*. It becomes lodged in the brain or spinal cord. Goats, cattle, and deer are also attacked by the same species.

Characteristics and Classification. — The flatworms belong to the phylum *Platyhelminthes*. They are unsegmented like the roundworms, but can be distinguished from the latter by the flattened condition of the body. The alimentary canal has only one external opening, the mouth. Food substances enter the mouth, and undigested particles are also cast out of this opening. In the tapeworm there is no mouth at all, the food being absorbed by the general body wall. All flatworms are hermaphroditic, since each individual is provided with both male and female reproductive organs. The parasitic habit of many flatworms has led to complicated life histories such as that of the liver fluke.

The three classes of the phylum are as follows: —

Class 1. TURBELLARIA. — Free-living animals like *Planaria*.

Class 2. TREMATODA. — Parasitic animals like the liver fluke.

Class 3. CESTODA. — Parasitic animals like the tapeworm.

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CHAPTER XXII

THE ECHINODERMS

THE *Echinodermata* or "spiny-skinned animals" are represented only by marine species. The common names applied to these animals are starfishes, brittle stars, sea urchins, sand dollars, sea cucumbers, and sea lilies. Echinoderms form quite a conspicuous part of the fauna of the seashore, but they are very seldom seen inland except in museums and curio cabinets. Their structure is very complex and very different from that of other animals, so much so that the term "aberrant" is often applied to the group. It will hardly pay us therefore to use much space in describing them or to spend much time in their study.

Symmetry. — The most notable thing about the echinoderms is their symmetry. All of the animals that we have studied thus far are bilaterally symmetrical. Animals are either symmetrical or asymmetrical, and the symmetrical animals are either bilateral or radial.

The bodies of bilaterally symmetrical animals are so constructed that the chief organs are arranged in pairs on either side of an axis passing from the head or anterior end to the tail or posterior end. There is only one plane through which their bodies can be divided into two similar parts. An upper or dorsal surface and a lower or ventral surface are recognizable, as well as right and left sides. Bilateral symmetry is characteristic of the most successful animals living at the present time, including all of the vertebrates and most of the invertebrates.

The starfishes and other echinoderms are built on an entirely different plan. Their bodies are made up of similar parts that radiate from a central axis; that is, they are radially symmetrical. These parts number in echinoderms either five or a multiple

of five. Radial symmetry is best suited to sessile animals, since the similarity of the parts enables them to obtain food or to repel enemies from all sides.

Starfishes. — The starfishes are common along many seacoasts, where they may be found usually upon the rocks with

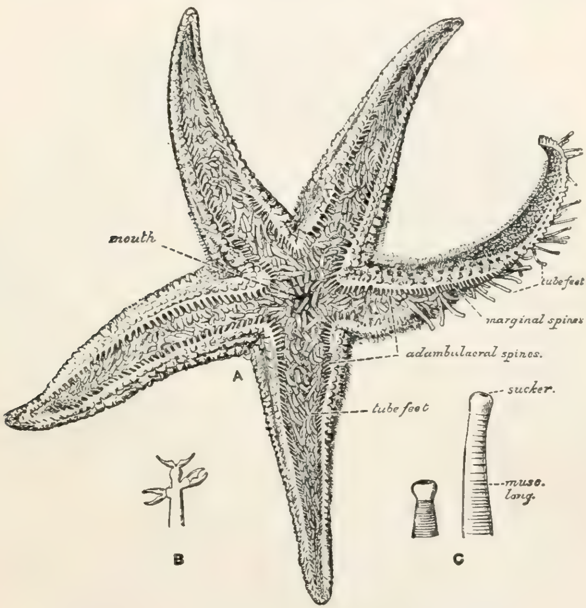

FIG. 113. — **A**, the oral surface of a starfish.

B, a spine bearing three pedicellariæ.
C, tube feet expanded and contracted. (From Cambridge Natural History.)

the mouth down. On the surface are many spines of various sizes, and on the under side are five grooves, one in each arm, from which two or four rows of tube feet extend (Fig. 113). The skeleton is made up of calcareous plates or ossicles bound together. The arms, however, are not rigid, but they may be bent slowly by a few muscle fibers in the body wall. The tube feet are also supplied with muscle fibers.

The *water-vascular system* is peculiar to echinoderms. Sea water is forced into this system of canals by cilia. The most interesting structures of the water-vascular system are the tube feet by means of which the starfish moves from place to place and holds its food.

The *food* of the starfish consists of fish, oysters, mussels, barnacles, clams, snails, worms, Crustacea, etc. When a mussel is to be eaten, the animal seizes it with the tube feet "and places it directly under its mouth, folding its arms down over it in umbrella fashion (Fig. 114). The muscles which run around the arms and disk in the body wall contract and partially turn the stomach inside out. The everted edge of the stomach is wrapped round the prey. Soon the bivalve is forced to relax its muscles and allow the valves to open. The edge of the stomach is then inserted between the valves and applied directly to the soft parts of the prey, which is thus completely digested. When the starfish moves away, nothing but the cleaned shell is left behind. If the bivalve is small, it may be completely taken into the stomach, and the empty shell later rejected through the mouth.

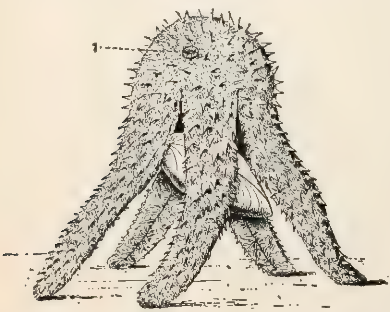

FIG. 114. — Diagram of starfish eating a mussel. (From Cambridge Natural History.)

Oyster beds are seriously affected by starfishes. One starfish which was placed in a dish containing clams devoured over fifty of them in six days. Formerly starfishes were taken, cut in two, and thrown back; this only increased the number, since each piece regenerated an entire animal. They are now often captured in a moplike tangle, to the threads of which they cling. They are then killed in hot water or thrown out on the shore above high-water mark and left to die in the sun.

Brittle stars. — The arms of the brittle stars and basket fish (Fig. 115) are noticeably different from those of the starfish. They are slender, and exceedingly flexible, but easily broken off; hence the name brittle star.

The food of the brittle stars consists of minute organisms

FIG. 115. — A basket star. (From Clark.)

and decaying organic matter lying on the mud of the sea bottom. It is scooped into the mouth by special tube feet. Locomotion is comparatively rapid. The arms are bent laterally, and enable animals belonging to certain species to "run," or climb, and probably to swim.

Sea Urchins. — The common sea urchin is almost spherical in shape, and covered with long spines, from among which the tube feet extend (Fig. 116). It lives principally on rocky shores, but it has such relatives as the sand dollars, which are flat like a silver dollar and bury themselves in the sand.

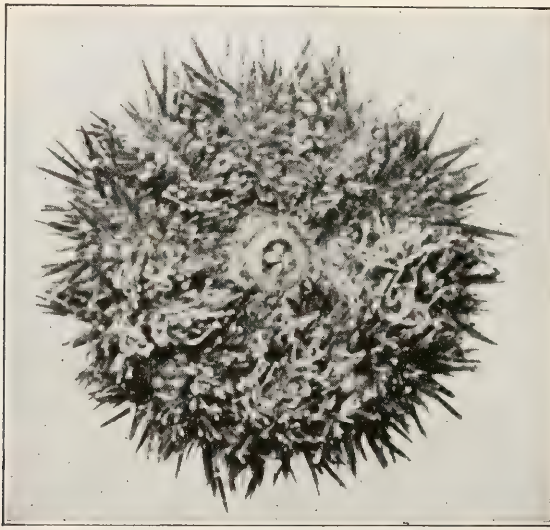

Fig. 116. — A sea urchin. (From Clark.)

Sea Cucumbers. — Sea cucumbers (Fig. 117) are so-called because of their resemblance to the garden vegetables of that name. They are not hard and spiny like their relatives, but have a thick, soft body wall. The tube feet around the mouth are modified as tentacles for obtaining food.

Their food consists of organic particles extracted from the sand or mud. Some species are said to stretch out their seaweedlike tentacles, on which many small organisms come to rest. "When one tentacle has got a sufficient freight, it is bent round and pushed into the mouth, which is closed on it.

It is then forcibly drawn out through the closed lips so that all the living cargo is swept off."

Among the South Pacific islands sea cucumbers are known as "bêche de mer" or "trepang" and are used for food. The trade mounts into hundreds of thousands of dollars annually.

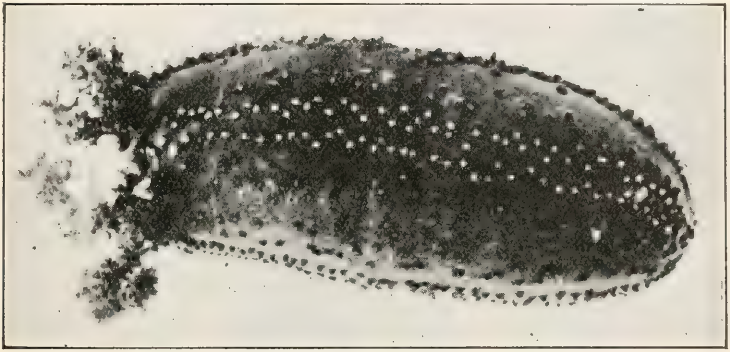

FIG. 117. — A sea cucumber. (From Clark.)

Sea Lilies. — The sea lilies or crinoids are now less abundant than the other echinoderms, but were very numerous in bygone eras, as indicated by their fossil remains so often found in limestone. They live usually at moderate depths and are therefore not seen so frequently along the coast.

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CHAPTER XXIII

THE CŒLENTERATES

THE animals known as corals, jellyfishes, polyps, sea anemones, sea fans, sea pens, and hydroids belong to the phylum *Cœlenterata.* They are all radially symmetrical, like the echi-

FIG. 118. — Hydras attached to water plants. (From Jammes.)

noderms, but very much less complex. Only a few of them live in fresh water, but one of these, named *Hydra*, after the mythological nine-headed dragon which was slain by Hercules, is abundant in ponds and streams, where it may be found attached by one end to aquatic vegetation (Fig. 118).

Hydra. — Hydras are easily seen with the naked eye, being from 2 to 20 mm. in length. They may be likened to a short, thick thread unraveled at the unattached distal end.

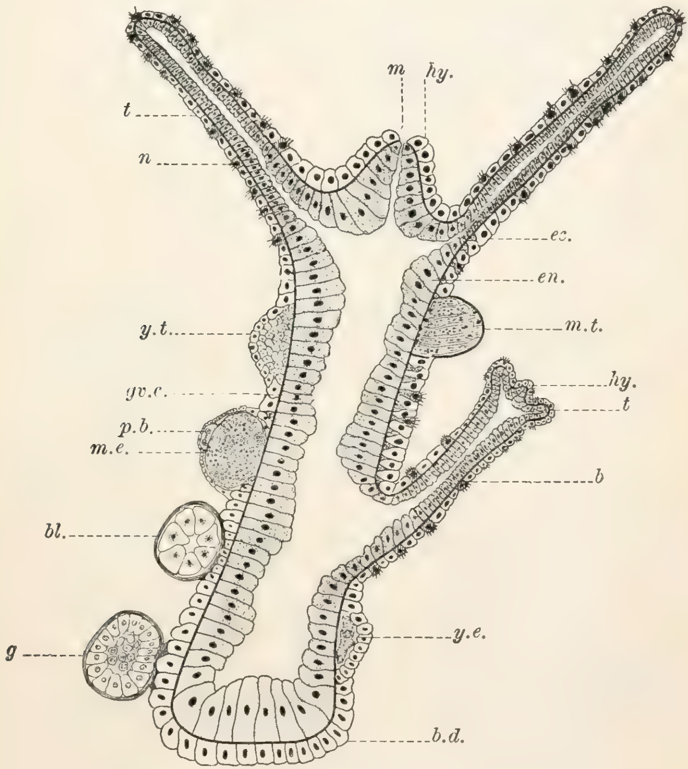

FIG. 119. — Diagram showing the structure of hydra.

b, bud; **b.d**, basal disk; **bl**, blastula; **ec**, ectoderm; **en**, entoderm; **g**, gastrula; **gv.c**, gastro-vascular cavity; **hy**, hypostome; **m**, mouth; **m.e**, mature egg; **m.t**, mature testis; **n**, nematocysts; **p.b**, polar bodies; **t**, tentacle; **y.e**, young egg; **y.t**, young testis. All the structures shown do not occur on a single animal at one time.

The body is really a tube (Fig. 119) usually attached by a basal disk (*b.d*) at one end, and with a mouth opening (*m*) at

the distal or free end. Around the mouth are arranged from six to ten smaller tubes, closed at their outer end, called tentacles (*t*). Both the body and tentacles vary at different times in length and thickness. One or more buds (*b*) are often found extending out from the body, and in September and October reproductive organs may also appear. The male organs (testes, Fig. 119, *y.t*) are conical elevations on the distal third of the body; the female organs (ovaries, Fig. 119, *y.e*, *m.e*) are knob-like projections near the basal disk.

HABITAT. — In spite of their simplicity *Hydras* are able to maintain themselves in the same habitat as that of aquatic insects, fish, frogs, etc., although they often fall a prey to these animals. When taken out of the water, *Hydra* shrinks into a shapeless lump, but when returned to the liquid, it soon becomes extended and regains its shape. Microscopic examination will show that its body is not supported by a skeleton of any kind and therefore must be held up by the water.

PROTECTION. — The protection afforded most animals by an exoskeleton is secured by Hydra with the aid of stinging organs, the nematocysts (Fig. 119, *n*; 120, B), that lie embedded in the surface, but are discharged when properly stimulated. Not only do these nematocysts protect the animal, but they also assist in capturing food. If a hungry *Hydra* is placed in a small amount of water containing small *Crustacea* such as *Cyclops* (see p. 141, Fig. 81), sooner or later a crustacean will strike a tentacle, and instead of continuing its progress will stop suddenly as though shot. And shot it really is, since the contact of its body with the *Hydra's* tentacle was all that was necessary to explode the nematocysts and paralyze the *Cyclops*. As soon as the *Cyclops* is captured the other tentacles bend over and help push it into the mouth.

ACTION OF NEMATOCYSTS. — The nematocyst acts in the following manner: Within it there is an inverted coiled, thread-like tube with barbs at the base. When the nematocyst explodes, this tube turns rapidly inside out and is able to pene-

trate the skin of other animals (Fig. 120, B, C, D). The explosion is probably due to internal pressure, and may be brought

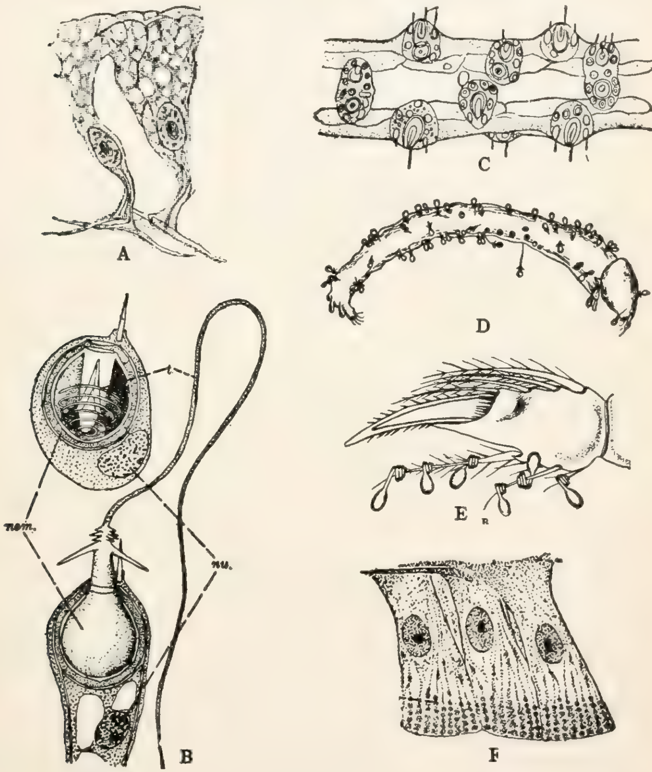

FIG. 120. — Parts of the body of hydra highly magnified.

A, two cells containing muscle fibers; **B**, two stinging cells or nematocysts; the lower one exploded; **C**, part of a tentacle showing groups of nematocysts; **D**, an insect larva shot full of nematocysts; **E**, nematocysts coiled around the spines on limb of a small animal; **F**, glandular cells from the basal disk. (After various authors.)

about by various methods, such as the application of a little acetic acid or methyl green. Many animals when "shot" by nematocysts are immediately paralyzed and sometimes killed

by a poison called hypnotoxin which is injected into them by the tube.

Two kinds of smaller nematocysts are also found in *Hydra.* One of these is cylindrical and contains a thread without barbs at its base; the other is spherical and contains a barbless thread which, when discharged, aids in the capture of prey by coiling around the spines or other structures that may be present (Fig. 120, E).

Division of Labor among Cells. — From a zoological standpoint *Hydra* is of special importance because it is one of the simplest of all the *Metazoa* or many-celled animals and gives us an excellent opportunity to study the division of labor among the different parts of the body.

The bodies of all complex animals including man are not continuous masses of the fundamental living substance, the protoplasm, but are broken up into millions of very small parts called cells. Each cell is separated from every other cell by means of partitions called cell walls. The term *cell* was first applied to these units of structure because when they were first noticed in cork they reminded their discoverers of the cells of monks in a monastery. These cells of which the bodies of animals are built up differ in size and shape, but as a rule the size of the animal depends on the number of cells rather than upon their size. The body of *Hydra* contains thousands of these cells arranged in two layers as indicated in Figure 119.

The Ectoderm of Hydra. — The outer layer, the *ectoderm,* is primarily protective and sensory, and is made up of two principal kinds of cells: some are shaped like inverted cones, and possess long contractile fibrils at their inner ends (Fig. 120, A); these enable the animal to expand and contract. The others lie among the bases of these muscular cells; they give rise to the three kinds of nematocysts or stinging cells and to nerve cells and germ cells.

The Entoderm of Hydra. — The *entoderm,* the inner layer of cells, is primarily digestive, absorptive, and secretory. The

digestive cells are large, with muscle fibrils at their base and whiplike threads, called flagella, or fingerlike processes, called pseudopodia, at the end which projects into the central cavity. The flagella create currents in the central cavity and the pseudopodia capture solid food particles. The glandular cells are small and without muscle fibrils (Fig. 120, F).

Between the ectoderm and entoderm is an extremely thin layer of jellylike substance called *mesoglea*.

Digestion. — Digestion takes place in the central or gastrovascular cavity (Fig. 119, *gv.c*) and probably also within the entoderm cells. The gland cells of the entoderm secrete a fluid into the gastrovascular cavity. This fluid dissolves the food. Digestion is aided by the currents set up by the flagella of the entoderm cells and by the churning resulting from the expansion and contraction of the body. Part of the food is evidently engulfed by the pseudopodia of the entoderm cells and undergoes intracellular digestion. The dissolved food is absorbed by the entoderm cells; part of it, especially the oil globules, is passed over to the ectoderm, where it is stored until needed.

Reproduction. — *Hydra* reproduces asexually by budding and by fission, and sexually by the production of eggs and spermatozoa. Budding (Fig. 119, *b*) is quite common, and may easily be observed in the laboratory. The bud appears first as a slight bulge in the body wall. This pushes out rapidly into a stalk, which soon develops a circlet of blunt tentacles about its distal end. When full grown, the bud becomes detached and leads a separate existence.

Fission is less common. The distal end of the animal divides first; then the body slowly splits down the center, the halves finally separating when the basal disk is severed.

The processes concerned in *sexual reproduction* are the production of spermatozoa and eggs, the fertilization of the egg, the development and hatching of the egg, and the growth of the young larva. The spermatozoa arise in the testis (Fig. 119,

m.t) and escape into the surrounding water. The eggs arise in the ovary (Fig. 119, *y.e*) and usually only one egg develops in a single ovary.

The egg (Fig. 119, *m.e*) is fertilized by a spermatozoon; it then divides into a number of cells and is known as an embryo (Fig. 119, *bl; g*). The embryo separates from the parent and falls to the bottom of the pond, where it remains unchanged for several weeks. At the end of this time the eggshell breaks away and the embryo escapes. A circlet of tentacles arises at one end; a mouth appears in their midst; and the young *Hydra* thus formed soon grows into the adult condition.

Regeneration. — The power of animals to restore lost parts was first discovered in *Hydra* by Trembley in 1744. This investigator found that if *Hydras* were cut into two, three, or four pieces, each part would grow into an entire animal.

Regeneration may be defined as the replacing of an entire organism by a part of the same. It takes place not only in *Hydra*, but in some of the representatives of almost every phylum of the animal kingdom. *Hydra*, however, is a species that has been quite widely used for experimentation. Pieces of *Hydra* that measure $\frac{1}{6}$ mm. or more in diameter are capable of becoming entire animals.

The benefit to the animal of the ability to regenerate lost parts is obvious. Such an animal, in many cases, will succeed in the struggle for existence under adverse conditions, since it is able to regain its normal condition even after severe injuries. Physiological regeneration takes place continually in all animals; for example, new cells are produced in the epidermis of man to take the place of those that are no longer able to perform their proper functions. In man, various tissues are capable of regeneration; for example, the skin, muscles, nerves, blood vessels, and bones. Lost parts are not restored in man because the growing tissues do not coördinate properly.

Division of Labor among Individuals of a Colony. — Whenever animals live together in colonies, there is almost certain to

be division of labor among the individuals. This has been noted in the honeybee (p. 63), where the females of the colony are of two kinds, queens and workers. Other social insects, such as ants, wasps, and termites, exhibit similar differences among the members of a colony. Division of labor likewise exists in communities of human beings, but the structural differences are not as great as in many of the lower animals. When division of labor occurs among the members of a colony, the form of the individual is usually modified so as to be suited to the function it performs. A colony containing two kinds of members is said to be *dimorphic;* one containing more than two kinds, *polymorphic*. Some of the most remarkable cases of polymorphism occur among the hydroids. The "Portuguese man-of-war" (Fig. 121), for example, consists of a float with a sail-like crest from which a number of polyps hang down into the water. Some of these polyps are nutritive, others are tactile; some contain batteries of nematocysts, others are male reproductive zooids; and still others give rise to egg-producing medusæ.

FIG. 121. — The Portuguese man-of-war, a colonial cœlenterate. (After Agassiz.)

Alternation of Generations. — Most of the relatives of *Hydra* live in the sea. Some of them are much branched, plantlike animals that look like a colony of *Hydras* attached to a central stem. These hydroids are of particular biological interest because of their method of reproduction. Reference to Figure

122 will make the following description clear. The hydralike members of the hydroid colony arise asexually by budding and serve to capture and digest food. Occasionally buds of a dif-

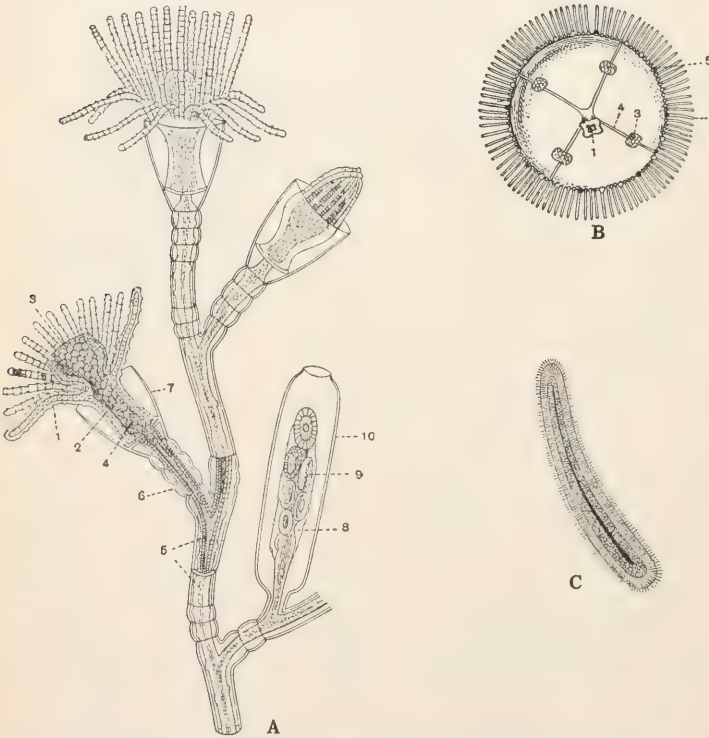

FIG. 122. — **A**, part of a colonial cœlenterate. **1**, ectoderm; **2**, entoderm; **3**, mouth; **4**, cœlenteron; **5**, cœnosarc; **6**, perisarc; **7**, hydrotheca; **8**, blastostyle; **9**, medusa-bud; **10**, gonotheca.

B, free-swimming medusa: **1**, mouth; **2**, tentacles; **3**, reproductive organs; **4**, radial canals; **5**, statocyst.

C, larva (planula). (From Parker and Haswell.)

ferent sort are formed; these undergo a second budding, but the buds thus produced do not remain attached to the colony. When they reach their full size, they separate from the parent

colony and swim away as jellyfish or medusæ. The medusæ produce eggs and spermatozoa. The eggs are fertilized by the spermatozoa, and these fertilized eggs develop into hydroid colonies. This rather complicated life history is described here for the purpose of illustrating the phenomenon of alternation of generations, also known as *metagenesis*. The asexual generation is represented by the budding colony; this produces the medusæ, which give rise to germ cells and thus constitute the sexual generation.

Jellyfish. — Some jellyfishes or medusæ belong to the class *Hydrozoa* along with *Hydra* and the hydroids just described, but most of them are placed in the class *Scyphozoa*. The mesoglea (see p. 203) of these animals is very thick, giving them a jellylike consistency. Medusæ are for the most part disk-shaped with a fringe of tentacles around the edge and oral arms hanging down around the mouth (Fig. 123). They swim slowly about in the sea by means of gentle undulations of the body.

FIG. 123. — A jellyfish swimming. (From Jammes.)

Sea Anemones. — Sea anemones are cylindrical animals with a crown of tentacles often so beautifully colored as to resemble

flowers (Fig. 124). They fasten themselves to stones, wharves, and other solid objects and very seldom move when once fixed. Small animals are captured by the tentacles as in *Hydra* and carried into the mouth.

Coral. — Corals are perhaps the most interesting members of the phylum *Cœlenterata.* Coral polyps live in colonies, and each member of the colony builds for itself a sort of skeleton

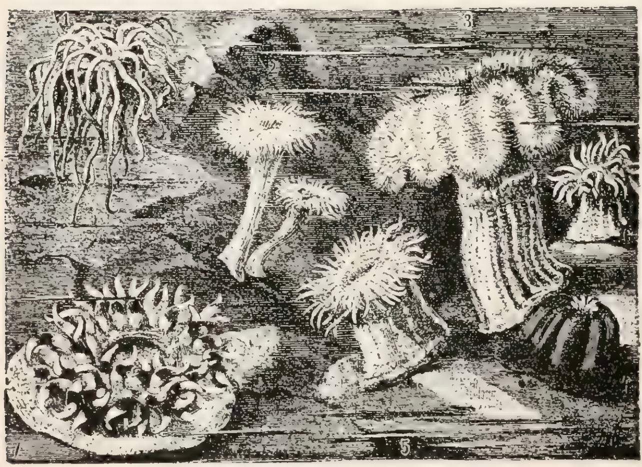

FIG. 124. — Sea anemones. (From Coleman.)

out of calcium carbonate which it extracts from the water. These skeletons constitute what we call coral.

Coral polyps build fringing reefs, barrier reefs, and atolls. These occur where conditions are favorable, principally in tropical seas, the best known being among the Maldive Islands of the Indian Ocean, the Fiji Islands of the South Pacific Ocean, the Great Barrier of Australia, and in the Bahama Island region.

A fringing or shore reef is a ridge of coral built up from the sea bottom so near the land that no navigable channel exists between it and the shore. Frequently breaks occur in the reef,

and irregular channels and pools are created which are often inhabited by many different kinds of animals, some of them brilliantly colored.

A barrier reef is separated from the shore by a wide, deep channel. The Great Barrier Reef of Australia is over 1100

FIG. 125. — Different kinds of coral.

A, organ-pipe coral; **B**, dead men's fingers; **C**, precious red coral; **D**, sea-pen. (From Sedgwick.)

miles long and incloses a channel from 10 to 25 fathoms deep and in some places 30 miles wide. Often a barrier reef entirely surrounds an island.

An atoll is a more or less circular reef inclosing a lagoon. Several theories have been advanced to account for the production of atolls. Charles Darwin, who made extensive studies of coral reefs and islands, is responsible for the subsidence theory.

According to Darwin, the reef was originally built up around an oceanic island which slowly sank beneath the ocean, leaving the coral reef inclosing a lagoon.

Besides producing islands and reefs, corals play an important rôle in protecting the shore from being worn down by the waves. They have also built up thick strata of the earth's crust.

FIG. 126. — Whitsunday Island in the South Pacific, an atoll built by corals. (After Darwin.)

Characteristics and Classification. — The cœlenterates are aquatic animals, mostly marine. They are radially symmetrical, have a single gastrovascular cavity, and are provided with stinging cells, the nematocysts.

The three classes of cœlenterates are as follows: —

Class 1. HYDROZOA. — Fresh-water Polyps, Hydroid Zoophytes, many small Medusæ or Jellyfishes, and a few stony Corals.

Class 2. SCYPHOZOA. — Most of the large Jellyfishes.

Class 3. ANTHOZOA. — Sea Anemones, most stony Corals, Sea Fans, Sea Pens, and precious Corals.

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CHAPTER XXIV

THE SPONGES

THE ordinary bath sponge is the skeleton of an animal that lives in the sea. Formerly sponges were considered plants because of their irregular and plantlike habits of growth, but their animal nature was finally established about 1857.

The fresh-water sponge lives in ponds and streams and may be found attached to the undersurface of rocks, dead leaves, or sticks (Fig. 127, A). It forms incrustations a fraction of an inch thick, or compact masses, and is gray or green in color.

Unfortunately the fresh-water sponge has a very complicated structure (Fig. 128, C) and is therefore not suited for laboratory work.

A Simple Sponge. — Most of the sponges live in the sea, and some of these are quite simple. For example, *Leucosolenia* (Fig. 127, B), which grows on the rocks just below low-tide mark, consists of a tube with side branches. The way the various physiological processes are carried on may be explained by means of Figure 128, A. One end of the sponge is fastened to the rock; the other end contains an opening, the osculum (*osc*). The cells lining the gastral cavity (*G.C*) are provided with whiplike projections called flagella (Fig. 129, D), which beat back and forth and create a current of water just as do the cilia in the mussel (see p. 148). This water is drawn in through pores in the body wall (Fig. 128, *p*) and passes out through the osculum in the direction of the arrows shown in the figure. Food particles are drawn into the gastral cavity with the water and engulfed by the cells. Waste matters pass out through the osculum suspended in the water. Oxygen is taken in by the body wall

and carbon dioxide and other excretory substances are given off by it.

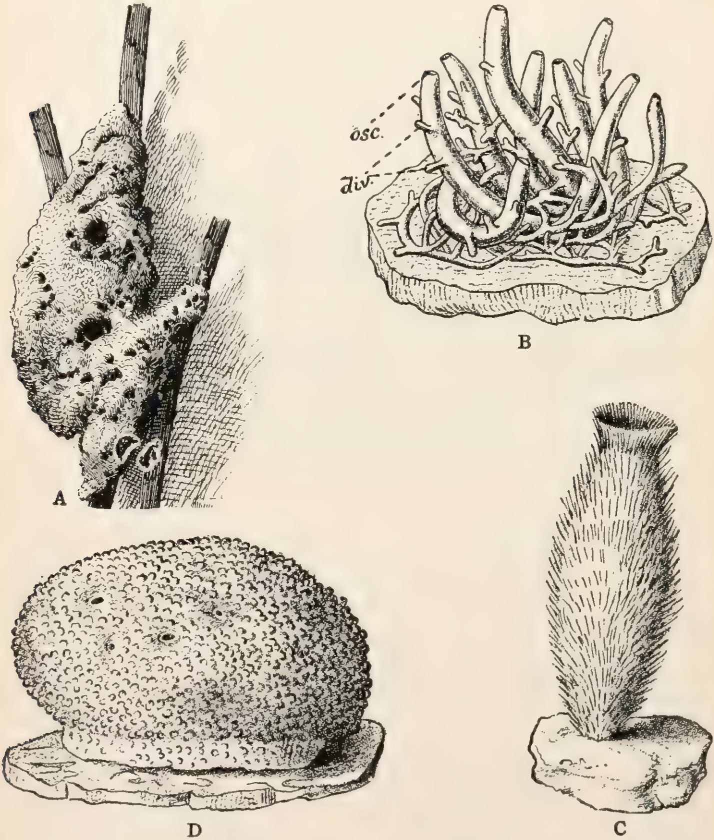

FIG. 127. — Types of sponges.

A, fresh-water sponge; **B**, a simple colonial marine sponge; **C**, a simple solitary marine sponge; **D**, a bath sponge. (After various authors.)

Reproduction. — New individuals are produced by budding, by the formation of gemmules, or by means of fertilized eggs. *Gemmules* (Fig. 129, C) are little balls of cells that are formed

in the autumn just before the death of the adult sponge. In the spring they develop into new sponges. They are of value in

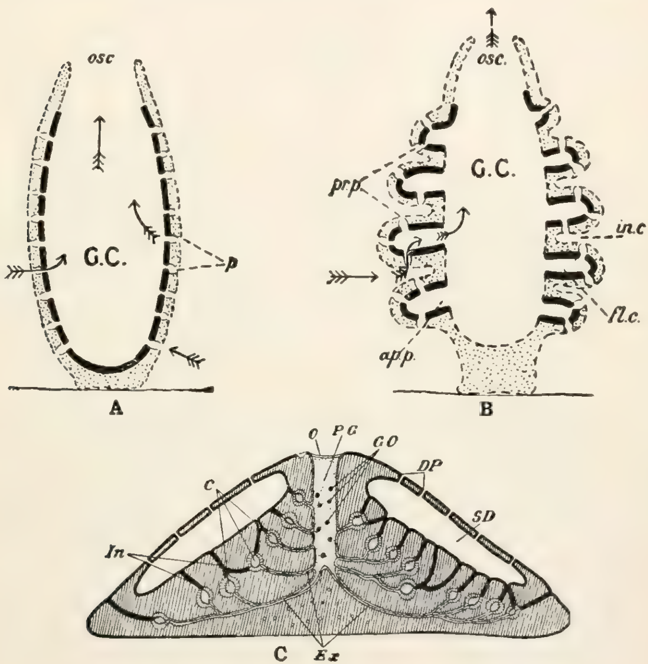

FIG. 128. — Types of canal systems of sponges.

A, ascon type; **B**, sycon type; **C**, rhagon type. The arrows indicate the direction of the current of water. The thick black line in **A** and **B** represents the gastral layer; the dotted portion, the dermal layer.

ap.p, apopyle; **fl.c**, flagellated chamber; **GC**, gastral cavity (cloaca); **in.c**, incurrent canal; **osc**, osculum; **pr.p**, prosopyle; **C**, flagellated chambers; **DP**, dermal pores; **Ex**, excurrent canals; **GO**, openings of excurrent canals; **In**, incurrent canals; **O**, osculum; **PG**, gastral cavity; **SD**, subdermal cavity. (From Minchin.)

carrying the race through a period of adverse conditions, such as the winter season. Only a few sponges reproduce in this way.

Grantia. — A sponge slightly more complex than *Leucosolenia* is *Grantia* (Fig. 127, C). *Grantia* also lives along the coast

attached to rocks just below low-tide mark. Its body wall is folded as shown in Figure 128, B. This folding increases the amount of surface of the body wall and consequently the number of cells. The result is a greater number of flagella, an increased current of water, and more food.

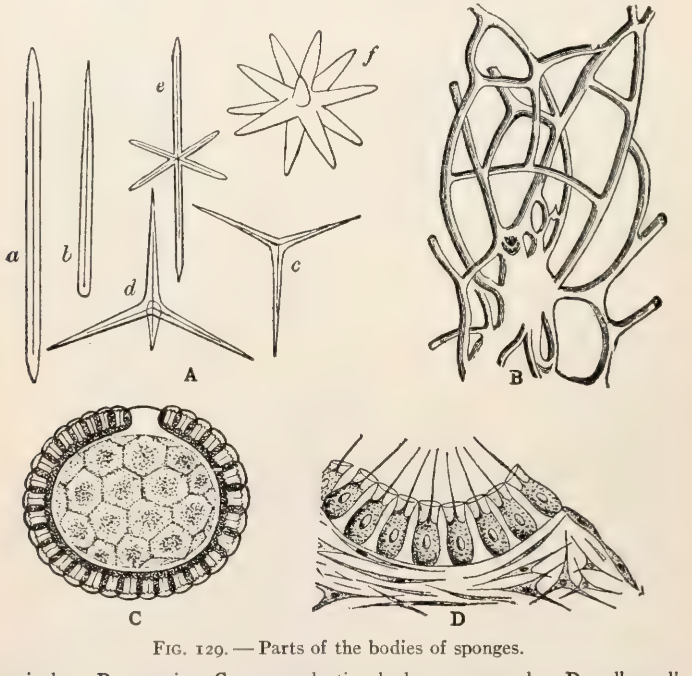

FIG. 129. — Parts of the bodies of sponges.

A, spicules; **B**, spongin; **C**, a reproductive body or gemmule; **D**, collar cells. (After various authors.)

Flow of Water in Fresh-water Sponge. — The fresh-water sponge is comparatively complex. Water passes through the pores (Fig. 128, C, *DP*) into a cavity (*SD*) just beneath the outer wall, then by way of incurrent canals (*In*) into chambers lined with flagellated cells (*C*), and from here through excurrent canals (*Ex*) into the gastral cavity (*PG*) and out through the osculum (*O*).

Spicules and Spongin. — The body wall of most sponges is supported by spicules of calcium carbonate or of silica (Fig. 129, A), and a few like the bath sponge have a skeleton of fibers consisting of a substance called spongin (Fig. 129, B).

The Relations of Sponges to Other Organisms and to Man. — Sponges are used as food by very few animals, since they are protected by spicules and by excretions of poisonous ferments,

Fig. 130. — Looking for sponges through a glass-bottom pail. (From Bul. U. S. Fish Com.)

making them distasteful. Nudibranch mollusks (see p. 164) feed on them to a certain extent.

The cavities of sponges offer shelter to many animals, especially *Crustacea* and cœlenterates; this may lead to a sort of partnership called commensalism. For example, certain hermit crabs protect themselves from attack by surrounding their shells with obnoxious sponges.

Oysters and other bivalves are often starved by sponges

which cover their shells and take away their food supply. Oyster culturists seek to prevent this by growing the bivalves in frames which are pulled up during a rain, thus killing the sponges with fresh water.

The origin of flint is in part due to the activities of sponges. It has been estimated that to extract one ounce of silicious spicules at least a ton of sea water must pass through the canal system of the sponge. The spicules aid in the formation

FIG. 131. — Bringing in a load of sponges. (From Bul. U. S. Fish Com.)

of flint, this substance being always associated with the remains of sponges and other organisms having silicious skeletons.

Of the commercial sponges, the common bath sponge, *Euspongia* (Fig. 127, D), is the most important. The best bath sponges come from the Mediterranean coast, Australia, the Bahamas, Florida, and the north coast of Cuba. They are gathered (Figs. 130, 131) by means of long hooks, by divers, or by dredging. They are allowed to decay, are washed, dried, and then sent to market.

The depletion of the sponge supply by unwise fishing has

resulted in an attempt to regulate the industry by governmental control. Sponge culture is now carried on successfully in Italy and Florida. Perfect specimens are cut into pieces about one inch square, and " planted " on stakes on clean, rocky bottoms free from cold currents. These grow into marketable size in five or six years.

Characteristics and Classification. — Sponges are mostly marine animals with bodies that are radially symmetrical but often irregular in shape. The body wall is permeated by many pores, and usually supported by a skeleton of spicules or spongin. Sponges are separated into three classes according to the composition and shape of their skeletal elements.

Class 1. CALCAREA. — With calcareous spicules, like *Grantia*.

Class 2. HEXACTINELLIDA. — With silicious spicules, like Venus's Flower Basket.

Class 3. DEMOSPONGIÆ. — With silicious spicules or spongin, like the Bath Sponge.

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CHAPTER XXV

THE PROTOZOA

WHAT we learned in Chapter IX regarding the minute animals that cause disease such as malarial fever should be enough to teach us the importance of the one-celled animals, the *Protozoa,* in the affairs of men. Such species as that which causes malaria are, however, not suitable for laboratory study since they can hardly be seen even with a compound microscope and are not available in a living condition. On the other hand, there are many animals consisting of a single cell which can be procured in abundance by simply bringing pondweeds or dry hay into the laboratory, placing it in a shallow dish, covering it with water, and then allowing it to decay for a few days. The scum that collects on the surface of such a " culture " or " infusion " will be found to contain many kinds of *Protozoa*, and the surrounding water will swarm with other species.

Paramecium. — The best species to begin with is the slipper animalcule, *Paramecium caudatum. Paramecia* are large enough to be seen with the naked eye if a proper background is provided. They are cigar-shaped animals with a depression called the *oral groove* (Fig. 132, *o.g*) extending from the forward end obliquely backward. The *mouth* (*m*) is situated near the end of this oral groove.

The motile organs are thin, threadlike *cilia* which beat back and forth and propel the animal forward or backward, and draw food particles into the mouth.

Just beneath the surface is a layer of spindle-shaped cavities filled with a semifluid substance. These are called *trichocysts*

(Fig. 132, *tr*), and are probably weapons of offense and defense. When a little acetic acid is added to the water, they explode, discharging long threads.

FOOD. — The food of *Paramecium* consists principally of minute plants and animals. The cilia in the oral groove (Fig. 132, *o.g*) create a current of water which forces the food particles down the gullet (*g*). At the end of the gullet a food vacuole (*f.v*) is produced; this when fully formed separates from the gullet and is swept away by the rotary streaming movements of the fluid within the body. This carries the food vacuole around a definite course, as shown by the arrows in Figure 132.

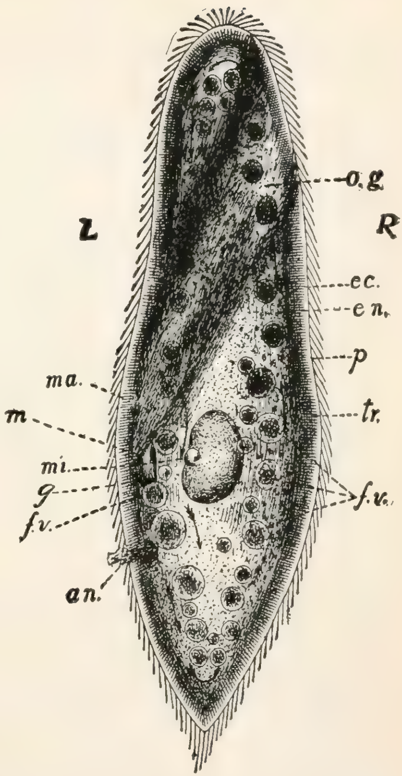


FIG. 132. — Paramecium viewed from the oral surface.

L, left side; **R**, right side.
an, anus; **ec**, ectosarc; **en**, endosarc; **f.v**, food vacuoles; **g**, gullet; **m**, mouth, **ma**, macronucleus; **mi**, micronucleus; **o.g**, oral groove; **p**, pellicle; **tr**, trichocyst layer. The arrows show the direction of movement of the food vacuoles. (From Jennings.)

PHYSIOLOGICAL PROCESSES. — *Digestion* takes place without the aid of a stomach. After a food vacuole has become embedded in the body an acid secretion enters through its walls and dissolves part of the food. Undigested particles, the feces, are ejected at a definite anal spot (Fig. 132, *an*).

The digested food, together with the water and mineral matter taken in when the food vacuole was formed, are absorbed by the surrounding protoplasm, and pass into the body substance of the animal, no circulatory system being present. These particles of organic and inorganic matter are then *assimilated;* that is, they are rearranged to form new particles of living protoplasm, which are deposited among the previously existing particles. The ability to thus manufacture protoplasm from unorganized matter is one of the fundamental properties of living substance.

The energy for the work done by *Paramecium* comes from the breaking down of complex molecules of protoplasm by oxidation or "physiological burning." This is known as *katabolism* or *dissimilation.* The products of this slow combustion are the energy of movement, heat, secretions, excretions, and the products of respiration.

The acid that is poured into the gastric vacuole by the surrounding protoplasm is of use to the animal and is known as a *secretion.*

Materials representing the final reduction of substances in the process of katabolism are called *excretions.* These are deposited either within or outside of the body. A large part of the excretory matter passes through the general surface of the body, but the two contractile vacuoles are also excretory in function.

A *contractile vacuole* is present near either end of the body. Each communicates with a large portion of the body by means of a system of radiating canals, six to ten in number. These canals collect fluid from the surrounding protoplasm and pour it into the vacuole. The vacuoles contract alternately at intervals of about ten to twenty seconds and their fluid contents are discharged to the outside. The contractile vacuoles are also *respiratory*, since carbon dioxide is probably also discharged from them. Oxygen dissolved in water is taken in through the surface of the body. As in higher animals this gas is necessary for life.

THE NUCLEUS. — In stained specimens of *Paramecium* a

highly colored body can be distinguished near the center of the animal. This is called the nucleus. Every cell possesses a nucleus. Reactions take place between the nucleus and the surrounding protoplasm, and that these reactions are important is proved by the fact that a cell deprived of its nucleus will not live very long.

Reproduction. — *Paramecium* reproduces only by simple *binary division*. This process is interrupted occasionally by a temporary union (conjugation) of two individuals. In binary fission the nucleus first divides and then the animal is divided into two by a constriction. The entire process occupies from about half an hour to two hours. The daughter *Paramecia* grow rapidly and divide again at the end of twenty-four hours or even sooner, depending on the temperature, food, and other external conditions. It has been estimated that one *Paramecium* may be responsible for the production of 268,000,000 offspring in one month.

Sometimes when two *Paramecia* come together in *conjugation*, they remain attached to each other with their ventral surfaces opposed, and a protoplasmic bridge is constructed between them. As soon as this union is effected, the nuclei pass through a series of complicated stages, during which part of the nucleus of each animal passes over into the other. This has been likened to the process of fertilization in higher animals. Then the two *Paramecia* separate and continue to grow and multiply by binary fission. The causes and results of conjugation are not well understood.

Reactions to Stimuli. — The reactions of *Paramecium* to changes in the water are quite interesting. It will swim away from salt if this is added to the water, but will swim into a drop of $\frac{1}{35}$ per cent acetic acid and stay there. It avoids a high temperature and swims against running water. These reactions prove that the animal is capable of being stimulated and of responding to these stimuli.

Life Activities of One-celled Animals and Many-celled Animals Compared. — If we now compare the life activities of *Parame-*

cium with those of the other animals we have studied, we find that they are similar in nature but are carried out by a single cell. *Paramecium* moves about, protects itself, captures food, digests food, circulates the digested food, assimilates it, produces secretions, excretes waste products, takes in oxygen, gives off carbon dioxide, responds to stimuli, and reproduces itself. The activities mentioned are all fundamental properties

FIG. 133. — Ameba.

1, nucleus; **2**, contractile vacuole; **3**, pseudopodia; **4**, food vacuoles; **5** grains of sand. (After Gruber.)

of the living substance, *protoplasm*. In *Paramecium* they are performed by a single cell without organs of any kind. In *Hydra* they are performed by many cells, and division of labor has taken place; that is, some cells are set aside for the performance of one function and others for other functions.

Ameba. — *Ameba* is a representative of another type of one-celled animals. It is only about $\frac{1}{100}$ inch in diameter, and is therefore invisible to the naked eye. Under the compound

microscope it looks like an irregular, colorless particle of animated jelly. Two regions are distinguishable in its body, the ectosarc and the endosarc. The *ectosarc* (Fig. 133, *3*) is the outer colorless layer. It is firmer than the endosarc and is free from granules. The *endosarc* is the large central mass of granular protoplasm. Within it lies the *nucleus* (Fig. 133, *1*), which is difficult to find in living *Amebæ*, but can easily be made out in animals that have been properly killed and stained. A *contractile vacuole* may be seen in favorable specimens.

Food. — The food of *Ameba* consists of very small aquatic plants and animals. The ingestion or taking in of food occurs without the aid of a mouth. Food may be engulfed at any point on the surface of the body, but it is usually taken in at what may be called the temporary anterior end; that is, the part of the body toward the direction of locomotion. A small amount of water is taken in with the food, so that there is formed a vacuole whose contents consist of a particle of nutritive material suspended in water. The whole process of food taking occupies one or more minutes, depending on the character of the food.

Physiological Activities. — The various physiological activities, such as digestion, assimilation, excretion, respiration, and reactions to stimuli, are similar to those in *Paramecium*.

Locomotion. — *Ameba* has no cilia such as cover the body of *Paramecium*, and moves in an entirely different way. The ectosarc bulges out into a fingerlike projection, the pseudopodium (Fig. 133, *3*), and then the endosarc flows into it. In this way the entire animal glides slowly along. There is, however, no permanent anterior end.

Reproduction. — Reproduction is by *binary fission* and by a process known as *sporulation*. There is a limit with regard to the size that may be attained by *Ameba* and when this limit is reached, the animal divides into two parts. First, the nucleus divides; then the animal elongates, a constriction appears near the center, and division into two daughter cells finally takes place.

Sporulation is apparently a rare process of multiplication in *Ameba*. First, the pseudopodia are drawn in and the animal becomes spherical. By successive divisions of the nucleus from five hundred to six hundred daughter nuclei are produced. Cell walls then appear, dividing the *Ameba* into as many cells as there are nuclei. These cells break away and grow into *Amebæ* in about three weeks.

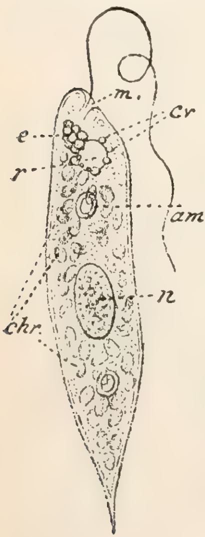


FIG. 134. — Euglena.

am, pyrenoid; **chr**, chromatophores; **cv**, contractile vacuoles; **e**, stigma, or eyespot; **m**, mouth; **n**, nucleus; **r**, reservoir. (From Bourne.)

Euglena. — A third type of *Protozoon* that may occur abundantly in laboratory cultures is the little greenish, spindle-shaped animal known as *Euglena* (Fig. 134). The principal interests *Euglena* has for us are its methods of *locomotion* and nutrition. At the anterior end of *Euglena* there is a long, whip-like filament which bends to and fro, drawing the animal along. This filament is called flagellum.

For its *nutrition*, *Euglena* probably does not ingest solid particles by means of its mouth (Fig. 134, *m*) and gullet, but manufactures its own food by the aid of the green substance (chlorophyll) contained in it (*chr*). As in plants, this chlorophyll is able, in the presence of light, to break down the carbon dioxide, thus setting free the oxygen, and to unite the carbon with water, forming a substance allied to starch, called paramylum (*am*). This mode of nutrition is known as *holophytic*. *Euglena* differs from most animals in its method of nutrition, since the majority of them ingest solid particles and are said to be *holozoic*.

Other Fresh-water Protozoa. — *Paramecium*, *Ameba*, and *Euglena* are only three of the more common *Protozoa* to be found in fresh water. A great many others will be seen on the slides

prepared in the laboratory, but only a few can be mentioned here. Two rather common ciliated species are *Vorticella* and *Stentor*. *Vorticella* is bell-shaped and attached to some object by a con-

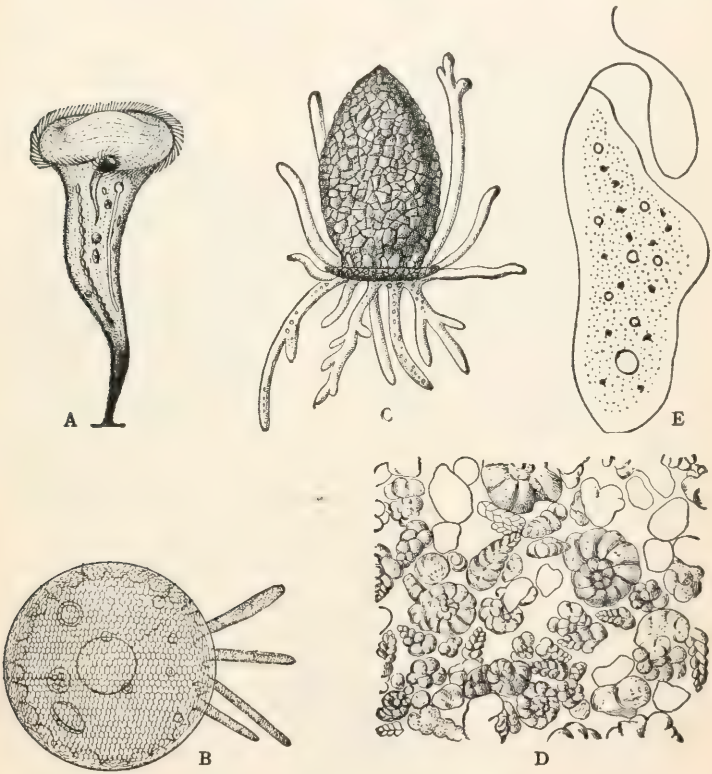


FIG. 135. — Types of protozoa.

A, stentor; **B**, arcella; **C**, difflugia; **D**, globigerina, etc., in gray chalk; **E**, mastigameba. (After various authors.)

tractile stalk. *Stentor* (Fig. 135, A) is trumpet-shaped and may be either attached or free-swimming. Some of the amebalike species are protected by shells. The doughnut-shaped *Arcella* (Fig. 135, B) and the pear-shaped *Difflugia* (Fig. 135, C) are

often found in fresh water, and in the sea the snail-like shells of *Globigerina* and many others occur in great abundance (Fig. 135, D). Two common flagellated *Protozoa* of the *Euglena* type

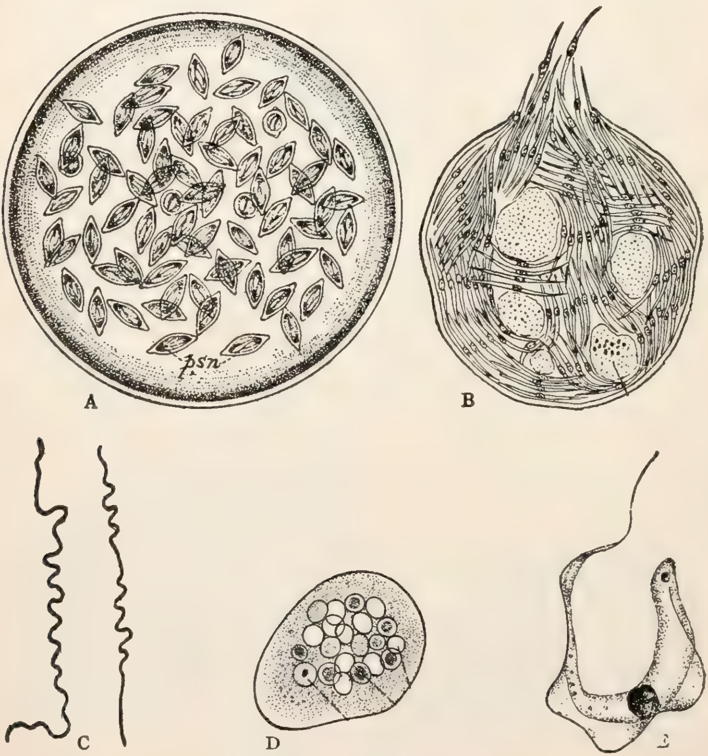


FIG. 136. — Parasitic protozoa.

A, a cyst of monocystis full of spores; **B**, a cyst of plasmodium with spores escaping; **C**, the germs which cause syphilis; **D**, entameba which causes dysentery; **E**, the germ which causes sleeping sickness. (After various authors.)

are *Mastigameba* (Fig. 135, E) and *Chilomonas*. *Mastigameba* looks something like an *Ameba* with a flagellum at one end. *Chilomonas* possesses two flagella.

Parasitic Protozoa. — And now we come to what are the most important of all *Protozoa*, the parasitic species. The easiest of these to obtain for purposes of study is known as *Monocystis* and lives in the reproductive organs (seminal vesicles) of the earthworm. It is about $\frac{1}{100}$ of an inch long and moves about somewhat like an *Ameba*. A very characteristic stage in its life history is that of the formation of spores (Fig. 136, A). Many of these spores are formed by a single animal, and each spore grows into a full-grown individual. *Protozoa* that reproduce in this way are known as *Sporozoa*.

The Malarial Parasite. — Perhaps the best-known *Sporozoon* is that which causes malarial fever and goes by the scientific name *Plasmodium vivax*. An account of how this parasite is transmitted from one person to another by mosquitoes has already been given (Chap. IX, p. 88). The spores when they are injected into the blood by the bite of the mosquito are slender, spindle-shaped bodies (Fig. 136, B). Each spore penetrates a blood corpuscle, becomes ameboid in shape, and feeds upon the substance of the corpuscle until it is demolished. The nucleus then divides several times, forming twelve or sixteen daughter nuclei, each of which becomes the center of a new spore. Soon the corpuscle wall breaks and the spores escape. This breaking down of the corpuscles causes a chill. The new spores enter other corpuscles and pass through a similar series of stages.

If the blood of a malarial fever patient is sucked up by an *Anopheles* mosquito, part of the spores become eggs in the stomach of the insect and part of them produce spermatozoa. The eggs are fertilized by the spermatozoa; the fertilized eggs become spindle-shaped and bore their way into the wall of the stomach, where they form little tumorlike swellings. In each of these a great many spores arise. They break out finally (Fig. 136, B) and make their way into the salivary glands of the mosquito and are then ready to be injected into the blood of another human being.

Pathogenic Protozoa. — *Protozoa* that cause diseases, like

the malarial parasite, are said to be pathogenic. Pathogenic *Protozoa* are all parasitic, living in the alimentary canal, blood, or other parts of the body. Many of them are known to attack man and other animals, but there is still a great deal to be learned about them. Two of the species that cause diseases in domestic animals are *Piroplasma bigeminum*, which is responsible for Texas fever in cattle (see Chap. XIII, p. 121), and *Spirochæta gallinarum*, which attacks poultry.

Human diseases that are definitely known to be caused by *Protozoan* parasites or are connected in some way with these minute germs are malarial fever, yellow fever, syphilis, yaws, recurrent fever, African tick fever, sleeping sickness, amebic dysentery, kala azar, hydrophobia, smallpox, and intestinal catarrh.

Amebic Dysentery. — Minute amebalike organisms, named *Entameba histolytica* (Fig. 136, D), are the cause of amebic dysentery, and are always found in the alimentary canal of patients suffering from this disease.

Hydrophobia and Smallpox. — Other ameboid organisms accompany hydrophobia and may destroy the nerve cells of the brain. In smallpox similar ameboid organisms attack and destroy the epithelial cells of the skin. Whether or not these structures are the direct cause of the disease mentioned or are merely accessories is not known, but they are to be looked upon as dangerous until they are proved to be harmless.

Sleeping Sickness. — In certain parts of tropical Africa flagellated *Protozoa* of the genus *Trypanosoma* (Fig. 136, E) cause the disease called sleeping sickness. Trypanosomes are also parasitic in rats and other animals. The species affecting man is carried from one person to another by a certain species of tsetse fly (see p. 99, Fig. 58, A). The parasite, after gaining access to the blood of a human being, multiplies with remarkable rapidity. The nervous system of the patient is affected either directly or by a poison secreted by the parasites. The disease may last several months or even years. Irregular fever

soon follows infection, and later general debility sets in. The victim exhibits an increasing tendency to sleep, gradually wastes away, and finally dies.

YELLOW FEVER. — As stated in Chapter IX (p. 86) we do not know what is the cause of yellow fever, but it is doubtless a germ of some kind, probably similar to the malarial fever parasite.

SPIROCHÆTES. — Spirochætes are corkscrew-shaped organisms about $\frac{1}{2500}$ of an inch long (Fig. 136, C). They are usually considered *Protozoa*, but their exact nature is not certainly known. Many of the most terrible of all diseases are caused by these minute living things.

YAWS is a disease of the tropics characterized by the presence of ulcerating sores on various parts of the body. It is caused by *Spirochæta pallidula*.

SYPHILIS likewise causes ulcerating sores. The organism responsible for this disease has been known for only a few years. It is *Spirochæta pallida*. Recently a drug known as dichlorhydrate-diamido-arseno-benzol has been discovered which seems to be an absolute cure for the disease.

RELAPSING OR RECURRENT FEVER (see p. 101) occurs in some parts of Europe. Another spirochæte, *Spirochæta obermeieri*, is the organism that causes it.

KALA AZAR OR DUMDUM FEVER (see p. 100) is a chronic disease in many parts of Asia and about the Mediterranean Sea. It is characterized by irregular fever, an enlarged spleen, and emaciation. The parasite that causes it is known as *Leishmania donovani*.

Control of Pathogenic Protozoa. — All of the diseases caused by pathogenic *Protozoa* are difficult to cure, and it is therefore important that their infectious nature be understood by every one, so that healthy people will not carelessly expose themselves and that diseased individuals will be careful not to distribute the parasites. Many of the protozoan parasites are transmitted by insects or mites and ticks, and methods of con-

trolling these germ carriers have been described in Chapters VIII, IX, X, and XIII. The control of the other diseases is largely a matter of care and cleanliness.

Protozoan Parasites of Domestic Animals. — The most important disease of domestic animals caused by a protozoon in this country is the Texas fever of cattle, described in Chapter XIII (p. 121). Besides this parasite there are a number of different species of trypanosomes, similar to that which causes sleeping sickness in man, that produce diseases in cattle, horses, and other domestic animals in various parts of the world.

The silkworm disease, *pebrine*, which appeared in the south of France at about the middle of the nineteenth century is especially interesting because of the fact that Pasteur's studies revealed its cause and devised methods for its control, thus paving the way for the control of infectious diseases in man. Pasteur advised the silkworm raisers to destroy all diseased caterpillars and eggs and to raise silkworms only from eggs that were free from parasites. This advice was followed and resulted in freeing the silk industry in France from the disease. The parasite is known as *Nosema bombycis*.

Protozoa in Drinking Water. — Our drinking water comes from three main sources. Rain water is pure except for the organisms that the rain drops gather in the air. Ground water, which comes from springs, wells, and infiltration basins, is usually free from *Protozoa*. Surface water from streams, lakes, ponds, and reservoirs contains more *Protozoa* than either rain water or ground water, and standing water is, as a rule, more crowded with them than running water.

The organisms that float passively in the water without seeking the shore or bottom constitute a group known as *plankton*. An examination of the waters of a typical river (the Illinois River) revealed 528 different species of plankton. These were mostly plants (algæ), *Protozoa*, wheel animalcules, and *Entomostraca* (see p. 144). One hundred and eighty-five of the 528 species recorded were *Protozoa*, and every cubic meter of

water contained an average of 112,000,000 protozoan individuals (Kofoid).

The numbers of *Protozoa* in different kinds of water are indicated by the following statistics (Whipple).

A flowing brook contained 10 per cubic centimeter.

A reservoir contained 97 per cubic centimeter.

A pond contained 666 per cubic centimeter.

The trouble caused by the *Protozoa* is chiefly due to their odor and taste. Besides this, *Protozoa* may cause temporary intestinal disorders in people not accustomed to a certain kind of water. On the other hand, some *Protozoa* undoubtedly aid in purifying water of *Bacteria;* for example, the flagellate *Bodo* greatly reduces the number of typhoid fever germs by using them for food.

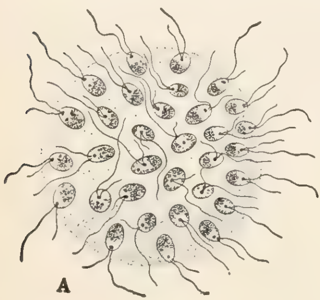
Some of the common species of *Protozoa* that cause trouble are *Uroglena* (Fig. 137, A), which has a fishy or oily odor; *Synura*, with an odor of ripe cucumbers and a bitter and spicy taste; and *Bursaria*, with an odor resembling that of a salt marsh.

The water in reservoirs may be purified by the use of copper sulphate (blue vitriol). About one part of copper sulphate to from five to twenty million parts of water should be used. This should be placed in a bag and dragged through the water behind a boat until all is dissolved and thoroughly distributed. Copper sulphate is poisonous, but the amount used is so small as to be harmless.

Colonial Protozoa. — *Protozoa* are said to be one-celled animals, but many species live more or less firmly fastened together in groups or colonies. In some cases the members of the colony are rather loosely united, as in *Carchesium*, a near relative of *Vorticella*, which occurs in groups fastened together by thin stalks. Other species may consist of many members embedded in a gelatinous matrix, such as *Uroglena* (Fig. 137, A), a relative of *Euglena*.

Volvox. — In one species, *Volvox globator* (Fig. 137, B), the members of the colony are connected with one another by strands

of protoplasm. *Volvox* is particularly interesting because it illustrates very clearly the division of labor between cells that are set aside for reproduction, the germ cells, and those that carry on the rest of the activities of the animal, the body cells or somatic cells. Certain reproductive cells of the *Volvox* colony grow very large, divide into a number of cells, and thus form new colonies. Other reproductive cells increase in size, some of them becoming eggs, and others dividing to form many spermatozoa (Fig. 137, B, ♂ and ♀). The eggs are fertilized by the spermatozoa, and after a period of rest develop into new colonies. The new colonies thus formed escape from the parent colony and continue the race, whereas the old colonies die a natural death. It is evident that unless germ cells were formed the *Volvox* race would soon disappear, and it is also clear that there is here a continuity of germ cells from one generation to



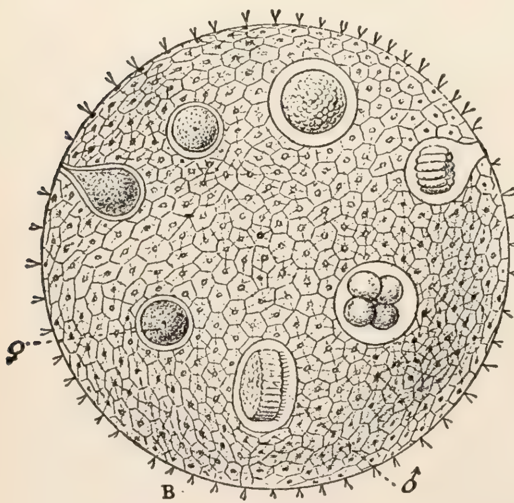


FIG. 137. — Colonial protozoa.
A, uroglena; **B**, volvox. (After Kölliker.)

another; that is, the germ cells of one generation, the parent colony, survive to produce the body and germ cells of the daughter colonies. A distinction between germ cells and body cells can be made in all the higher animals including man, and, as in *Volvox*, the parents produce germ cells (eggs and spermatozoa) which give rise to the body and germ cells of the young.

Characteristics and Classification. — *Protozoa* are one-celled animals which in many cases form colonies. They live in fresh water, salt water, damp earth, and as parasites in or on the bodies of other animals. They vary in shape from the shapeless *Ameba* to the highly organized *Vorticella*. Locomotion takes place by means of cilia and pseudopodia. The various physiological processes occur in *Protozoa* just as they do in higher organisms, but within a single cell and without definite organs.

The *Protozoa* are separated into classes according to the presence or absence of locomotor organs and the character of these when present. Four classes are usually recognized: —

Class 1. RHIZOPODA. — With pseudopodia, as in *Ameba*.

Class 2. MASTIGOPHORA. — With flagella, as in *Euglena*.

Class 3. SPOROZOA. — Without locomotor organs in adult state. Produce spores, as in malarial parasite.

Class 4. INFUSORIA. — With cilia, as in *Paramecium*.

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CHAPTER XXVI

AN INTRODUCTION TO THE VERTEBRATES

THE animals that remain to be discussed all belong to the phylum of back-boned creatures, the *Vertebrata*. There are only about thirty thousand species of these as compared with over four hundred thousand *Invertebrates*, but their large size and intimate relations with man make them of comparatively greater importance. Unlike the invertebrates, the vertebrates are well known to us, although there are many of them that never come within our ordinary, everyday experiences. The vertebrates may be divided into five classes, which are as follows, beginning with the lowest forms: —

Class 1. PISCES. — Fishes (Fig. 138, A and B).

Class 2. AMPHIBIA. — Frogs, Toads, and Salamanders (Fig. 138, C and D).

Class 3. REPTILIA. — Lizards, Snakes, Crocrodiles, and Turtles (Fig. 138, E and F).

Class 4. AVES. — Birds (Fig. 138, G).

Class 5. MAMMALIA. — Hairy Quadrupeds, Whales, Seals, Bats, Monkeys, and Man (Fig. 138, H).

Most of us have seen examples of all these different classes of vertebrates. The horse is a typical mammal; the hen or pigeon a typical bird; the snake, turtle, and crocodile typical reptiles; the frogs and toads typical amphibians, and fish are, of course, a common article of food. Although we thus have an idea of the different types of vertebrates, they are mostly domesticated animals, and we do not see very many different kinds of wild vertebrates unless we are fortunate enough to live where there are aquaria containing fish and other aquatic animals, or

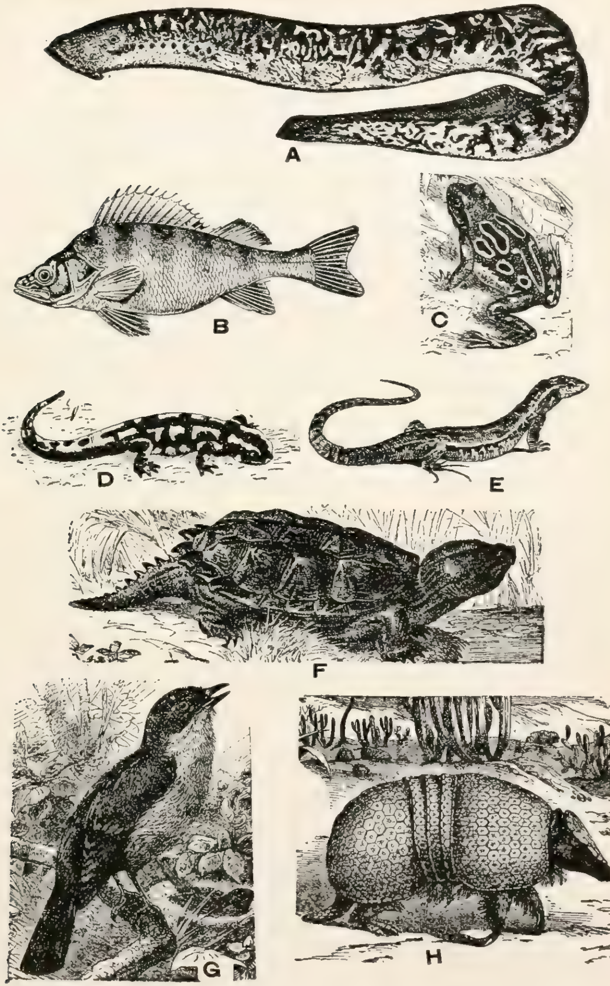

FIG. 138. — Types of vertebrates.

A, a cyclostome (eel); **B**, a fish; **C**, an amphibian (frog); **D**, an amphibian (salamander); **E**, a reptile (lizard); **F**, a reptile (turtle); **G**, a bird; **H**, a mammal (armadillo). (From various authors.)

zoological gardens with living wild animals, or museums with exhibits of stuffed animals. Many of us have had a chance to see a few different kinds of wild creatures in circuses and have therefore some idea of their appearance.

According to some authorities we should not study any animals that we cannot see in the laboratory, but while it is certainly true that we remember what we see better than what we read about, still we can obtain by means of descriptions and pictures rather accurate ideas of animals we have never seen on the basis of what we know of familiar creatures. In the same way does our knowledge of the lakes, rivers, and creeks, the hills and the plains enable us to study intelligently similar forms in Africa and other foreign lands which we have never seen. It is, therefore, the plan of our discussion of the classes of vertebrates to point out first the peculiarities in the structure of the animals which adapt them to their surroundings, and then with the aid of pictures to describe a few of the more important members of each class.

The activities of these different groups of vertebrates are often very diverse, and the structures that adapt them to their different habitats are quite varied; nevertheless the plan of structure is similar in all. The best example of the vertebrates that is small enough to be used conveniently in the laboratory, and that can be obtained for large classes without prohibitive labor and expense, is undoubtedly the frog. Fish answer these requirements also, but their construction differs more widely from that of man than does the anatomy of the frog. It is desirable that we learn as much as possible about man from our study of the lower animals, and the best method of beginning is to study the most available vertebrate, comparing its structures and physiological processes with those of human beings. The frog will therefore be discussed quite fully in the succeeding chapter.

The Body as a Machine. — The body of a vertebrate, such as the frog or man, may be considered a sort of machine consisting of many complex parts. There are, of course, many differences

between a living animal and a machine like a clock, but just as a boy takes a clock apart to see what makes it go, so if we wish to know what enables an animal to perform its various activities, we must dissect it and examine its various parts.

Organs and Systems of Organs. — The principal parts of an animal, such as the eye, the stomach, or the arm, we call *organs*. Many organs are usually necessary for the performance of a single function; for example, the proper digestion of food in a complex animal requires a large number of organs collectively known as the alimentary canal and its appendages. These organs constitute the digestive system. Similarly, other sets of organs are associated for carrying on other functions. The principal *systems of organs* and their chief functions are as follows: —

(1) Digestive system — Digestion and absorption of food.

(2) Circulatory system — Transportation of food, oxygen, and waste products.

(3) Respiratory system — Taking in oxygen and giving off carbon dioxide.

(4) Excretory system — Elimination of the waste products of metabolism.

(5) Muscular system — Motion and locomotion.

(6) Skeletal system — Protection and support.

(7) Nervous system — Sensation and correlation.

(8) Reproductive system — Reproduction.

(1) The *digestive system* has for its functions the changing of solid food into liquids and the absorption of these liquids into the blood. This system consists usually of a tube, the alimentary canal, with an opening at either end of the body. Connected with this tube are a number of glands. Solids taken in as food are usually broken up in the mouth, where they are mixed with juices from the salivary glands; the mixture then passes through the œsophagus into the stomach, where chemical digestion, aided by secretions from the gastric glands, takes place; it then enters the intestine, which absorbs the dissolved material

through its walls. Undigested solids travel onward into the rectum and are cast out through the anus as feces.

(2) The *circulatory system* transports the absorbed food to all parts of the body. It also carries oxygen to the tissues, and carbon dioxide and other waste products away from the tissues. These substances are transported by fluids called blood and lymph, which are usually confined in tubes, the blood vessels, and in irregular spaces known as sinuses. The blood consists of a plasma and corpuscles. It is forced to the various parts of the body by the contractions of a muscular organ called the heart.

(3) The *respiratory system* takes in oxygen (inspiration) and gives off carbon dioxide (expiration). In many animals, like the earthworm, the oxygen and carbon dioxide pass through the moist surface of the body, but in higher animals there is a special system of organs for this purpose. Aquatic animals usually possess gills which take oxygen from the water. Terrestrial animals generally take air into cavities in the body, such as the lungs of man and the tracheæ of insects.

(4) The *excretory system* is necessary for the elimination of waste products which are injurious to the body. These waste products result from the oxidation of the protoplasm. Various names are applied to the organs of excretion, such as nephridia and kidneys.

(5) The *muscular system* enables animals to move about in search of food and to escape from their enemies. Many animals, like the oyster, have the power of motion, but not of locomotion. The muscles would be of slight efficiency were it not for the hard skeletal parts to which they are attached and which serve as levers.

(6) The *skeletal system* is either external (exoskeleton) or internal (endoskeleton). The hard shell of the crayfish is an example of an exoskeleton; the bones of man form an endoskeleton. In either case the skeleton not only supports and protects certain soft parts of the body, but it also provides places for the attachment of muscles.

(7) The *nervous system* in higher animals consists of two parts: (*a*) central and (*b*) peripheral. The brain and spinal cord constitute the central nervous system. The organs of special sense, such as sight, smell, taste, hearing, touch, temperature, and equilibrium, and the nerves connected with them, and all other nerves connecting the central nervous system with various parts of the body, constitute the peripheral nervous system. Efferent (motor) nerve fibers conduct impulses from the brain and nerve cord to an active organ like a muscle or gland.

(8) The *reproductive system* consists of the germ cells, and the organs necessary for furnishing yolk and protective envelopes, and for insuring the union of the eggs and spermatozoa. The essential reproductive organs in complex animals are usually the ovaries, which contain the eggs, and the testes, in which the spermatozoa ripen. The accessory organs are generally ducts leading to the exterior, glands connected with these ducts, and organs for transferring the spermatozoa from the male to the female.

Structure of Organs. — We cannot understand how an organ performs its duty unless we have a knowledge of the structure of the organ. We shall not attempt to learn all there is known about organs, but just enough to understand their activities. In the first place the entire body, as previously stated (p. 202), is either a single cell (*Protozoa*, p. 218), a colony of cells (colonial *Protozoa*, p. 231), or a many-celled organism with the cells closely bound together (*Metazoa*). We have seen how the various physiological processes are performed by a single cell (Fig. 139), as in *Paramecium* (p. 218), and also how in many-celled animals like *Hydra* (p. 202) groups of cells are set aside for carrying on different functions, that is, division of labor has taken place. This is true of all many-celled animals.

Protoplasm. — The substance of which every cell is composed is called protoplasm. As in *Paramecium* (p. 219) every cell contains a central body, the *nucleus*. The nucleus is a

specialized kind of protoplasm; it is sometimes called nucleoplasm to distinguish it from the rest of the protoplasm, which is designated cytoplasm.

Protoplasm the Physical Basis of Life. — Protoplasm is known as the physical basis of life since every organism, whether

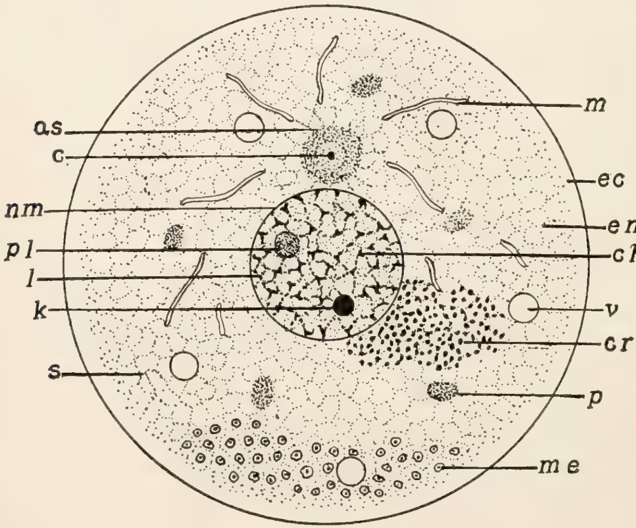

Fig. 139. — Diagram of a typical cell.

as, astrosphere; **c**, centrosome; **ch**, chromatin; **cr**, chromidia; **ec**, ectoplasm; **en**, entoderm; **k**, karyosome; **l**, linin; **m**, mitochondria; **me**, metaplasm; **nm**, nuclear membrane; **p**, plastid; **pl**, plasmosome or nucleolus; **s**, cytoplasm; **v**, vacuole.

plant or animal, has this substance as a basis. We should therefore know something more about it. *Ameba* (Fig. 133) consists of naked protoplasm. The outer layer is very clear, and rather firm like stiff jelly; the inner mass is granular and more watery. The activities of *Ameba* are those of animals in general, but in the *Metazoa* these activities are distributed among many cells, a condition known as division of labor among cells or specialization.

THE FUNDAMENTAL PROPERTIES OF PROTOPLASM. — The fundamental properties exhibited by *Ameba* are: —

(1) Irritability, the ability of responding to changes in the surroundings.

(2) Contractility, as indicated by the changes in the shape of the body.

(3) Metabolism, that is, the change of food into protoplasm and the use of this protoplasm to furnish energy — processes that involve digestion, absorption, circulation, assimilation, oxidation, secretion, and excretion.

(4) Growth, which is the result of an excess of the building-up process (anabolism) over the breaking-down process (katabolism); and

(5) Reproduction.

These are not only fundamental properties of *Ameba*, but of protoplasm in general.

COMPOSITION OF PROTOPLASM. — The substances of which protoplasm is composed are chiefly oxygen, carbon, hydrogen, and nitrogen. These substances do not differ from those in lifeless bodies but they are so combined as to form the peculiar substance *protoplasm* which occurs only in living things.

Tissues. — The division of labor among the cells of the many-celled animals has resulted in changes in the size, shape, and structure of the cells. For example, muscle cells are the agents of active movement and therefore their contractile powers are strengthened and their other properties correspondingly weakened. Groups of cells that are associated for the performance of certain functions are called tissues. We have already noted in the case of *Volvox* (p. 231) the distinction between the reproductive or germ cells and the somatic or body cells, and have seen that the reproductive cells are of two kinds, female cells or eggs (Fig. 140, A) and male cells or spermatozoa (Fig. 140, B).

KINDS OF TISSUES. — The body cells form tissues of many kinds, but these can be classified according to their functions and structure into four groups: —

(1) Movements are performed by *muscular tissue*. This tissue is made up of muscle cells, either voluntary or involuntary. The voluntary muscle cells form muscles that are controlled by the will of the animal; they are cross-striated (Fig. 140, E). Involuntary muscles cannot be controlled; they are smooth and non-striated (Fig. 140, F).

(2) The perception of changes in the surroundings and the conduction of impulses are functions of *nervous tissue*. Nerve cells are peculiar structures consisting of a nucleated central body, from which branches and nerve fibers extend (Fig. 140, G). These nerve fibers may be several feet in length, extending, for example, from the lower part of the backbone in man to the toes.

(3) The various parts of the body are bound together by *connective tissues*, such as tendons, and held upright and protected by *supporting tissues*, such as bone and cartilage (Fig. 140, D). The substances in these tissues are largely of nonliving fibers, plates, and masses produced by living cells.

(4) The body surface and the surfaces and linings of organs are composed of *epithelial tissues*. The epithelial tissues covering the body serve as a protection, and contain nerve endings, glands, hairs, etc. (Fig. 140, C).

Living and Lifeless Things. — Living things differ from lifeless things in being

(1) of definite size, and not of any size like water which may exist as a particle of vapor or as an ocean;

(2) of definite form, and not of varied form like water,

(3) of definite organization into cells;

(4) capable of growth by the addition of new particles among preëxisting particles;

(5) able to reproduce others of their kind; and

(6) able to move. The movement of a thing is usually enough to indicate that it is alive, but many living things, such as a hen's egg, are unable tc move; hence in many cases we must consider the other five characteristics first listed in order to determine whether a thing is alive or not.

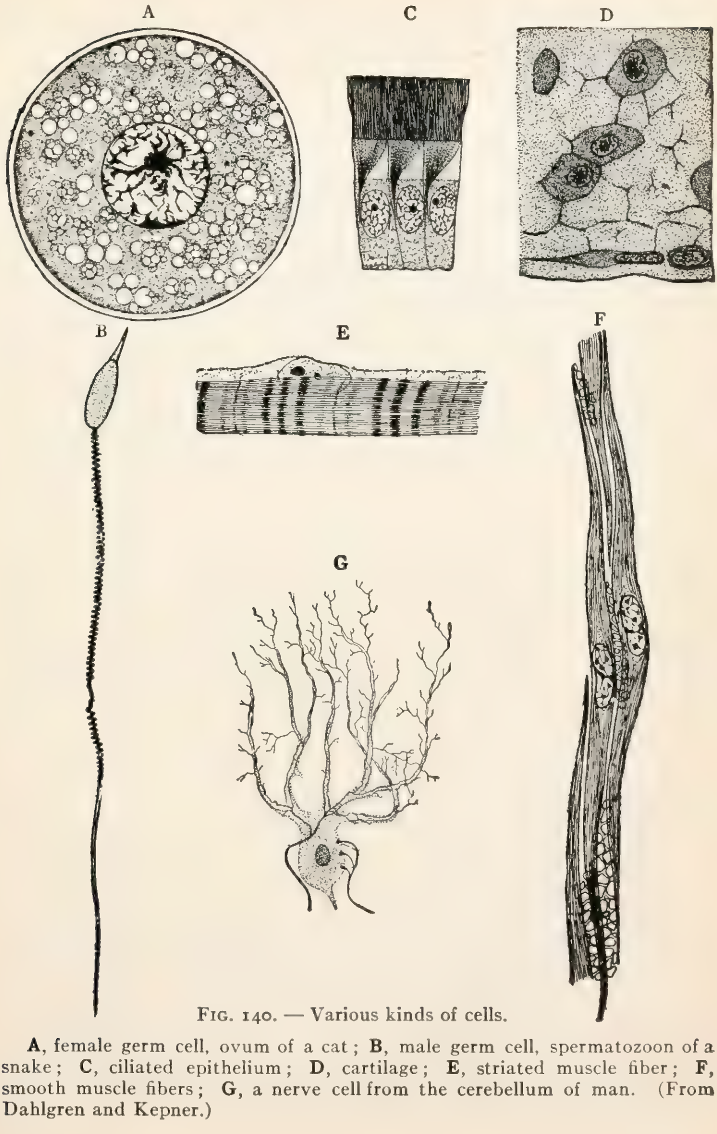

FIG. 140. — Various kinds of cells.

A, female germ cell, ovum of a cat; **B**, male germ cell, spermatozoon of a snake; **C**, ciliated epithelium; **D**, cartilage; **E**, striated muscle fiber; **F**, smooth muscle fibers; **G**, a nerve cell from the cerebellum of man. (From Dahlgren and Kepner.)

The Origin of Life. — Scientists have speculated for centuries regarding the place where life originated upon the earth. According to the theory of spontaneous generation animals were supposed to originate directly from inorganic substances; for example, frogs and toads from the muddy bottom of ponds under the influence of the sun, and insects from dew. The brilliant experiments of Redi (1668), Pasteur (1864), and Tyndall (1876) overthrew this theory completely, and scientists now believe that living organisms originate only from preëxisting organisms. Where life first began is still unknown, but the meeting point of sea and land is the most probable place of origin. From here the fresh water, deep sea, and land were gradually peopled.

This general view of protoplasm, cells, tissues, organs, and systems of organs will make more intelligible the discussion of the life processes of the frog presented in the next chapter.

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CHAPTER XXVII

THE FROG, A TYPICAL VERTEBRATE

Frogs live in or near fresh-water lakes, ponds, and streams, and are distributed over the entire North American continent as well as in other parts of the world. Frogs have many enemies, being preyed upon by snakes, turtles, cranes, herons, other frogs, and man. They have no means of protection and must therefore remain concealed from their enemies or escape by rapid locomotion. Those who have looked for frogs amid the water plants in a pond or in the grass and rushes along the banks of streams will readily admit that their colors effectively conceal them from view. If they are approached too closely, they have an excellent refuge, the water, into which their hind legs quickly propel them. As is the case with the snails, the skin of the frog is naked and covered with mucus which impedes evaporation. Because of this naked skin frogs must live in very damp places or near enough to water so that they can take a plunge occasionally or else their skins will become dry and they will perish.

Movements. — The ordinary movements of the frog are those employed in leaping, diving, crawling, burrowing, and maintaining an upright position. Some of these movements are due to internal causes such as hunger, but many of them are the responses to external stimuli. Frogs are sensitive to light, and tend to congregate in shady places. They also seem to be stimulated by contact, as shown by their tendency to crawl under stones and into crevices.

The frog leaps on land and swims in the water. The hind legs are large and powerful. When the frog is on land, the hind legs are folded up, and a sudden extension propels the

body through the air. Likewise in swimming the hind legs are alternately folded up and extended, and during their backward stroke the toes are spread apart so as to offer more resistance to the water. Frequently frogs float on the surface with just the tip of the nose exposed and with the hind legs hanging down. If the frog is disturbed in this position, the hind legs are flexed, a movement which withdraws the body, the fore legs direct the frog downward, and the hind legs are extended, to complete the dive.

Croaking. — Frogs croak most during the breeding season, but they are heard also at other times of the year, especially in the evening or when the atmosphere becomes damp. Croaking may take place either in air or under water. In the latter case the air is forced from the lungs, past the vocal cords, into the mouth cavity, and back again.

FIG. 141.—Diagrams showing the movements of a frog's tongue when an insect is captured. (From Cambridge Natural History.)

Physiological Processes. — The physiological processes of the frog will be considered in the following order: (1) digestion, (2) absorption, (3) assimilation, (4) circulation, (5) respiration, (6) excretion, (7) secretion, (8) the skeleton and its functions, (9) muscular activity, (10) nervous activity, (11) sense organs, (12) reproduction.

DIGESTION. — The worms and insects used as food by the frog are captured by its sticky *tongue* (Fig. 141) and drawn into the *mouth* by this organ or pushed in with the forefeet. The conical *teeth* that are present in the upper jaw do not masticate the food as do man's, but simply hold it. In man the salivary glands add their secretions to the food as it is being masticated and this saliva converts the starch in the food into sugar. There are no salivary glands in the frog and hence this process of salivation is entirely omitted.

Food passes from the mouth through the tubelike *œsophagus* into the *stomach* (Fig. 142, *M*). The walls of the stomach are thick and muscular and contain a great many glands for the secretion of *gastric juice.* These glands are stimulated by the presence of food, and the gastric juice they secrete acts upon the

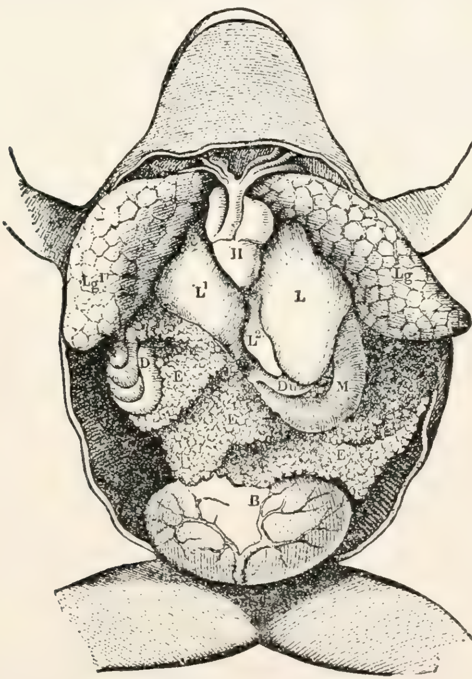

FIG. 142. – Internal anatomy of the frog.

B, bladder; **D**, intestine; **E**, ovaries; **H**, heart; **L**, liver; **Lg**, lungs; **M**, stomach. (From Ecker.)

food particles in such a way as to dissolve them. This solution of food material in preparation for absorption is the object of digestion.

The food next passes into the intestine where the *pancreatic juice* from the pancreas, and the *bile*, which is stored up by the

liver in the gall bladder, are added to it. Both the pancreatic juice and bile aid in dissolving the food, and they are helped more or less by secretions from glands in the intestinal wall. The movements of the food through the alimentary canal are due chiefly to what are called *peristaltic waves;* the circular muscles in the walls relax ahead and contract behind, thus forcing the food along.

ABSORPTION. — The digested food passes into the cells of the intestinal wall, where it is more or less changed, and then transferred to the blood or lymph. This is the process of absorption. Very little is known about absorption in the frog. In human beings the absorbed food, part of it having passed through the liver, is carried to the heart, whence it is pumped through the body.

ASSIMILATION. — The extraction of the digested food from the blood stream by the cells of the body, and the formation of new protoplasm with it, constitute the process of assimilation. Lifeless things cannot grow in this way, but must increase in size by the addition of substances on the outside.

CIRCULATION. — The blood which circulates throughout the body carries the digested food and distributes it to the cells, bears oxygen from the breathing organs to the tissues and carbon dioxide away from the tissues to the breathing organs, and transfers waste products from all parts of the body to the excretory organs.

Blood is a fluid containing *red corpuscles* and *white corpuscles.* The red corpuscles owe their color to the presence of *hæmoglobin.* This substance combines with oxygen in the breathing organs and gives it out again to the tissues. The white corpuscles resemble *Ameba* in shape and are hence said to be ameboid. They act as scavengers, engulfing foreign bodies such as germs and broken-down tissues that may find their way into the blood stream.

The discovery that the *blood circulates* was made by an English physician, William Harvey, in 1621. Since then it has been

shown that the entire blood supply passes from the heart throughout the body and back again to the heart in from twenty to thirty seconds. This means that the six quarts of blood in the body of a man pass three or four thousand times per day throughout the tissues of the body.

The *heart* (Fig. 143) of the frog is a conical organ consisting of a muscular *ventricle* and two thin-walled *auricles*. In man there are two ventricles instead of one. Tubes, the *arteries*, carry the blood from the heart to the tissues, and others, the *veins*, carry it back to the heart. The muscular ventricle by its contractions forces blood into the arteries. The walls of the arteries are elastic and by their pressure force the blood along until it reaches the finest of all the blood tubes, the *capillaries*. The capillaries unite the ends of the arteries with the ends of the veins and the blood from the former passes through them into the veins and thence back to the heart.

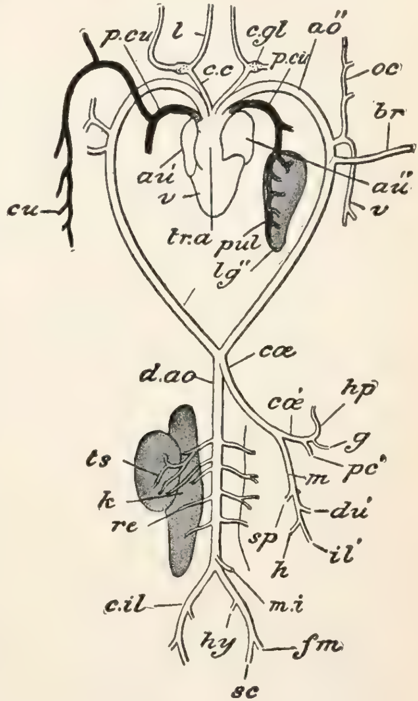

FIG. 143. — Diagram of the arterial system of the frog, ventral view.

ao″, aortic arch; **au′**, right auricle; **au″**, left auricle; **br**, brachial artery; **c.c**, carotid; **c.gl**, carotid gland; **c.il**, common iliac; **cœ**, cœliaco-mesenteric; **cœ′**, cœliac; **cu**, cutaneous; **d.ao**, dorsal aorta; **fm**, femoral; **g**, gastric; **h**, hœmorrhoidal; **hp**, hepatic; **hy**, epigastrico-vesical; **k**, kidney; **l**, lingual; **lg″**, left lung; **m**, anterior mesenteric; **m.i**, posterior mesenteric; **oc**, occipital; **pc′**, pancreatic; **p.cu**, pulmocutaneous; **pul**, pulmonary; **re**, renal; **sc**, sciatic; **sp**, splenic; **tr.a**, truncus arteriosus; **ts**, testis; **v**, vertebral. (After Howes.)

The movement of the blood through capillaries can be observed very easily in the web of the frog's foot.

Part of the blood of the frog is forced by the heart into the lungs (Fig. 143, *lg''*), where it gets rid of carbon dioxide and receives oxygen. Another part of the blood is carried to the kidneys (Fig. 143, *k*) and is there relieved of its waste products. The blood returning from these and other organs is carried either through the liver to the right auricle or directly to this auricle, with the exception of that from the lungs, which enters the left auricle. From the auricles the blood is sucked through valves into the ventricle when this muscular portion expands after a contraction.

There are many spaces in the frog's body filled with a colorless fluid called *lymph*, which contains colorless corpuscles. Lymph passes from one space into another, enters the blood, and it is always gently flowing over the tissues, thus aiding the blood in the performance of its functions.

RESPIRATION. — By respiration is meant the transfer of oxygen from the air to the blood and from the blood to the cells of the body, and of carbon dioxide from the cells to the blood and from the blood to the air. We are accustomed to consider breathing as the act of respiration, but this is only *external respiration* and not so essential as the *internal respiration* of the cells.

In the frog, respiration takes place to a considerable extent through the *skin*, both in water and in air, but it is carried on principally by the *lungs* (Fig. 142, L, L'). During inspiration air passes through the nostrils into the mouth cavity. The nostrils are then closed and the air is forced through a slit, the glottis, into a short tube, the larynx, and thence into the lungs. Air is expelled from the lungs (expiration) into the mouth cavity by the contraction of the muscles of the body wall.

The lungs are pear-shaped sacs with thin, elastic walls. The area of their inner surface is increased by folds which form minute chambers called *alveoli*. Blood capillaries are numerous in the walls of these alveoli.

In an average human being the lungs can hold about 330 cubic inches of air, but at each inspiration only about 30 cubic inches of this is renewed. The fresh air drawn in differs from the expired air as follows:—

	Oxygen	Nitrogen	Carbon Dioxide	Water
Inspired air	20.96%	79.00%	0.04%	Trace
Expired air	16.02%	79.00%	4.38%	0.60%

The inspired air therefore loses oxygen, which is nearly replaced in expired air by carbon dioxide. This change is due to the passage of oxygen from the hæmoglobin in the red blood corpuscles, and the transference of carbon dioxide from the blood corpuscles into the lung cavities. The oxygen obtained by the blood in this way is carried to the tissues and delivered to the cells.

We may explain why the cells must have oxygen as follows: Every action of an animal uses up part of the protoplasm in the body, and just as coal furnishes the power for the work done by a steam engine so food supplies the protoplasm for doing the work of the animal. The breaking down of the protoplasm is caused by the union of oxygen with it, producing a kind of slow combustion or *oxidation*. The burning of substances like wood in air is an example of rapid combustion, and the rusting of iron an example of slow combustion. In every case oxygen unites chemically with the substances.

Oxidation within the cells results in the performance of work, and the breaking down of the protoplasm is accompanied by the production of carbon dioxide and nitrogenous waste substances. The carbon dioxide is carried to the lungs by the blood and there excreted. The nitrogenous substances are carried chiefly to the kidneys. The processes included in the taking up of oxygen by the protoplasm of the cells and the giving off of carbon dioxide constitute what is known as *internal respiration*.

One result of combustion is the production of heat. In man and other mammals and birds the body is kept at an even temperature by the oxidation of protoplasm regardless of how cold the surrounding air is. These animals are "warm-blooded." The frogs and other vertebrates and the invertebrates are all "cold-blooded," since the little heat that is produced is lost rapidly. Their bodies are usually about the same temperature as their surroundings.

Excretion. — The waste products resulting from the oxidation of protoplasm are carried by the blood to the excretory organs. The cells of these organs take the waste matter from the blood and excrete it. Some of it is excreted by the skin, liver, and intestinal walls, but most of it is taken from the blood in the two kidneys.

The kidneys contain a great many coiled tubes (uriniferous tubules) into which the excretions pass. From these tubes they are carried into one large tube, the *ureter*, in each kidney, and from these into a thin-walled sac, the *bladder* (Fig. 142, B). From time to time the walls of the bladder contract and force the excretory matter out of the body through the anal opening. Excretions are poisonous to the animal and must be removed from the body. If an animal's excretory organs do not perform their functions properly, serious sickness results.

Secretion. — We have found that excretions are of no use to the body, but are really injurious and must be cast out to avoid sickness. Secretions, on the other hand, are of use to the animal; in fact, life would be impossible without them, since, for example, without saliva, gastric juice, pancreatic juice, and bile, digestion would be impossible and starvation would result, even where food is abundant.

Secretions are produced within special secretory cells. When a number of these cells are grouped together by connective tissue, the resulting organ is designated a *gland*. Glands of various complexity are present in the body of the frog. In the skin are simple, saclike *mucous glands* and *poison glands* (Fig. 144).

As their names indicate, some of these glands manufacture mucus, others poison. These substances are secreted into the central cavity of the gland and then forced out upon the skin through a thin tube or duct. The glands in the walls of the stomach, which secrete gastric juice, are simple in structure, but unlike the glands in the skin are sometimes branched. Other glands are more complex, some resembling a bunch of grapes, like the salivary glands in man. The liver and pancreas have already been mentioned as secreting digestive juices; they are likewise very complex.

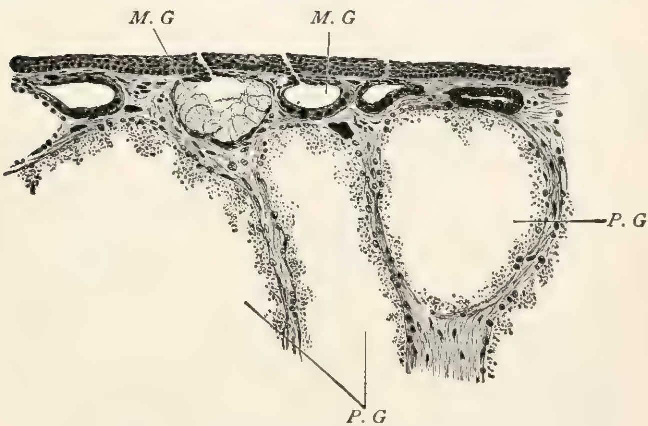

FIG. 144. — A section through the skin of a frog. **M.G**, mucous gland; **P.G**, poison gland. (From Holmes.)

A few glands in both the frog and man have no ducts leading to the alimentary canal or elsewhere, but their secretions pass directly from their cells into the blood. These are known as ductless glands and their products as *internal secretions*. Glands with ducts, like the liver and pancreas, may also form internal secretions.

The *spleen* is a rounded, reddish, ductless gland that lies near the end of the intestine in the frog. The function of its internal secretion is not fully known. Other ductless glands are the

thyroid and *thymus* situated in the neck region, and the *adrenal bodies* extending along the ventral surface of the kidneys. The removal of any of these glands, as a rule, is followed by irregularities in the work done by the various organs of the body and sometimes ends fatally. On the whole, internal secretions are extremely important for the proper functioning of the various parts of the body. They seem to act as regulative agents, and thus secure the coördination of the different functions. All glands are not for secretive purposes only, but, like the kidney, may excrete waste products.

The Skeleton and its Functions. — The skeleton of an animal supports the softer parts, furnishes points of attachment for muscles, and protects various organs. Most of the invertebrates possess *exoskeletons* such as that of the insect or crayfish. The vertebrates, on the other hand, are provided with an internal framework or *endoskeleton*. This consists of bone and cartilage. That bone contains cartilage can easily be determined if a piece is placed in hydrochloric acid. The acid dissolves out the mineral constituents which give the bone rigidity, leaving the cartilage, which furnishes pliancy and elasticity.

The skull and vertebral column are often spoken of as the axial skeleton, and the bones which support the appendages (arms and legs) as the appendicular skeleton. The accompanying figure (Fig. 145) shows the bones in the skeleton of a frog.

The bones of the *skull* form a brain case or *cranium* which protects the brain, and *auditory* and *olfactory capsules* which protect the sense organs of hearing and smell respectively. Besides these, the bones of the face (jaw bones, etc.) and of the throat (hyoids) are included in the skull.

The backbone or *vertebral column* serves as a central axis. It consists of a series of bones called *vertebræ* which are held together by ligaments, but move upon one another so that the body can be bent. Each vertebra bears a dorsal arch which surrounds and protects the spinal cord.

The bones which unite the fore limbs to the body constitute

the *pectoral girdle*. The principal ones are the breastbone or *sternum*, the shoulder blades or *scapulæ*, and the collar bones or *clavicles*.

The bones of the fore limbs are very similar to those of man and other vertebrates. They are the arm bone or *humerus*,

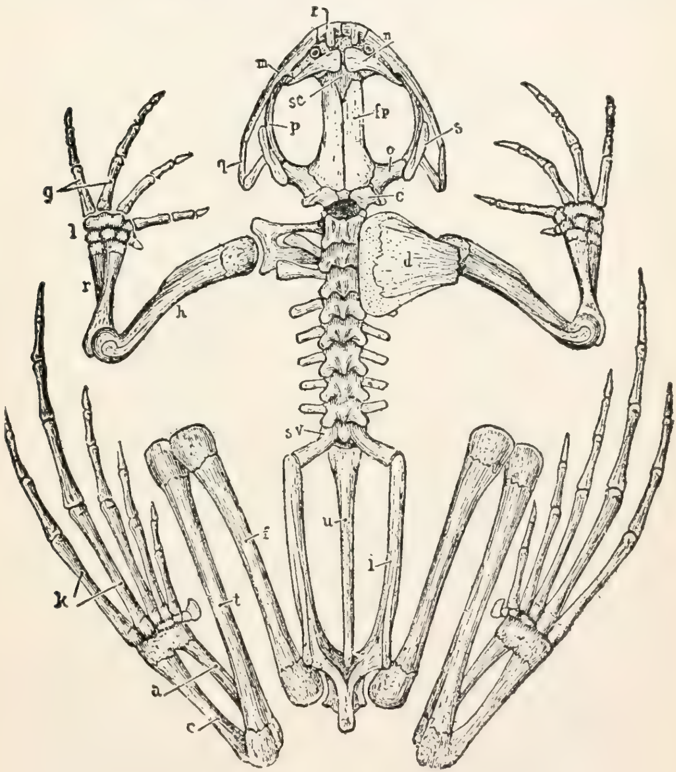

FIG. 145. — Skeleton of the frog.

the forearm or *radio-ulna*, the *wrist* containing six small bones, and the *hand* with a row of bones in each of the five *digits*.

The hind limbs are attached to the vertebral column by the *pelvic girdle* consisting of three bones on each side closely fused

together. Each leg contains a thigh bone or *femur*, a leg bone or *tibiofibula*, four small *ankle* bones, five rows of bones in the *digits*, and an extra digit bone, the *prehallux*.

Various kinds of *joints* are represented in skeleton of the vertebrates. Some of these are *immovable*, such as those of the cranium; others are *movable*. The fore limbs and hind limbs form *ball-and-socket joints* with the pectoral and pelvic girdles; the knee and elbow joints work like a *hinge;* the bones of the wrists and ankles form *gliding joints;* and the bones of the forearm (radius) in some vertebrates form a sort of *pivot* at the elbows.

Muscular Activity. — As already pointed out the muscles consist of specialized contractile cells and are the agents of active movement. The " flesh " of vertebrates is largely muscle. As a rule these muscles are attached by one or both ends to bones either directly or by means of bands of connective tissue, the *tendons*. Movements depend upon the attachment of the muscles and the kinds of joints between the bones.

Most of the large muscles of the frog are used in leaping and are consequently in the hind limbs (Fig. 146).

A few of these are as follows: (1) The *sartorius* bends the hind leg, drawing it forward and ventrally; (2) the *gastrocnemius* bends the hind leg and extends the foot; (3) the *adductor magnus* bends the thigh ventrally; (4) the *rectus internus major* bends the hind leg; and (5) the *peroneus* extends the hind leg and foot. The *pectoralis major* moves the fore limbs.

These are all *voluntary muscles*. Most of the muscles of the interior organs are *involuntary;* those in the wall of the bladder are excellent examples of this type and can be examined easily.

Nervous Activity. — The nervous system of vertebrates is more complex than that of any other animals. In fact, man owes his dominance over other animals to the great development of his brain. The central nervous system consists of the brain and spinal cord; the peripheral nervous system consists of the cerebral and spinal nerves; and a sympathetic system is also present.

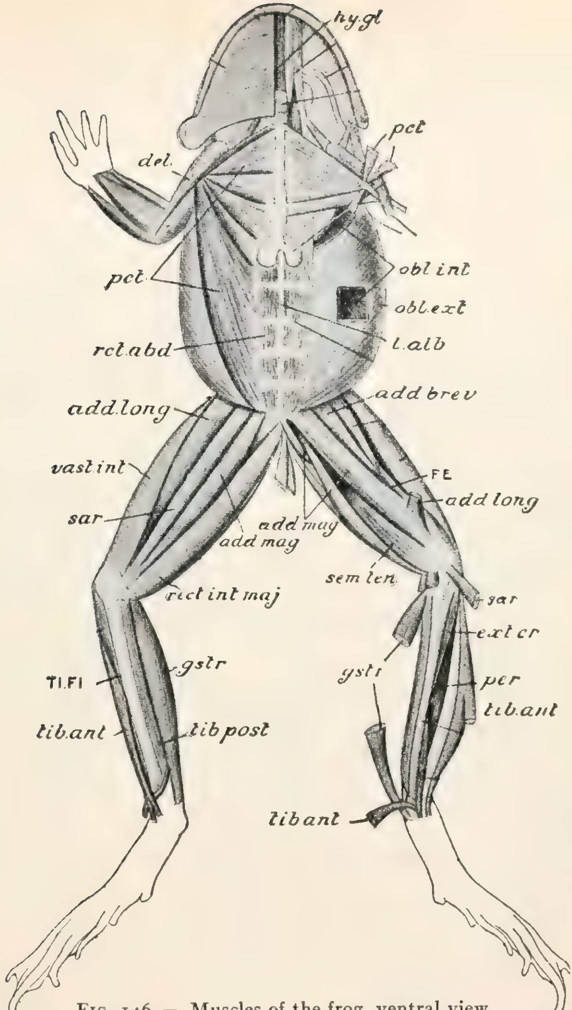

FIG. 146. — Muscles of the frog, ventral view.

add.brev, adductor brevis; **add.long**, adductor longus; **add.mag**, adductor magnus; **del**, deltoid; **FE**, femur; **gstr**, gastrocnemius; **hy.gl**, hyoglossus; **l.alb**, linea alba; **obl.int**, obliquus internus; **obl.ext**, obliquus externus; **pct**, pectoralis; **per**, peronæus; **rct.abd**, rectus abdominis; **rect.int.maj**, rectus internus major; **sar**, sartorius; **sem.ten**, semi-tendinosus; **tib.ant**, tibialis anticus; **tib.post**, tibialis posticus. (From Parker and Haswell.)

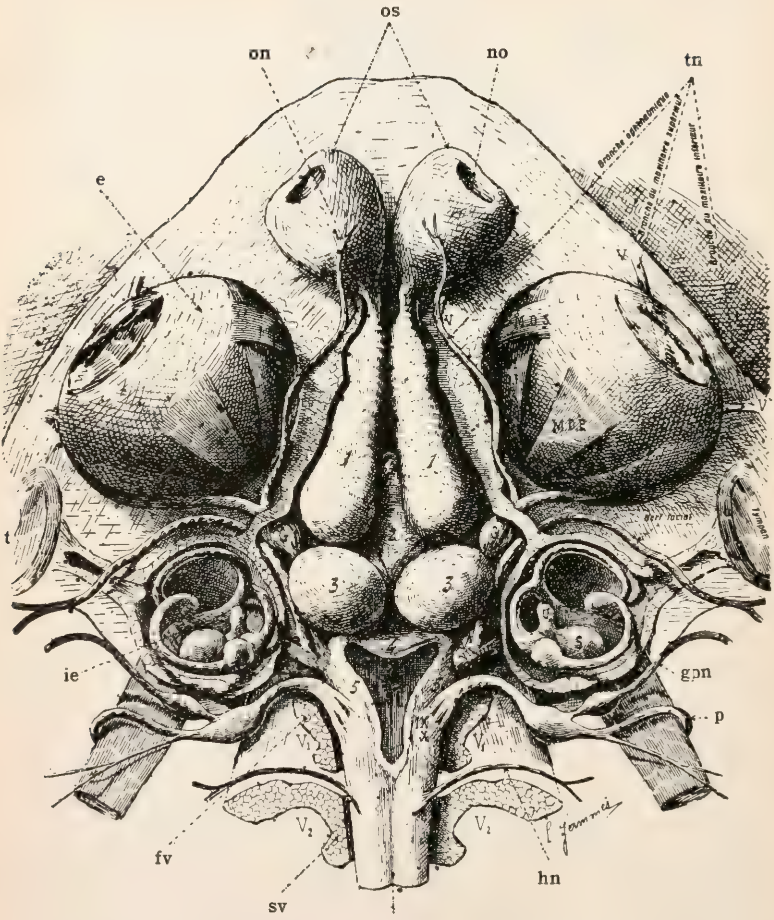

FIG. 147. — Nervous system and sense organs in the head of the frog.

1, cerebrum; **2**, mid-brain; **3**, optic lobes; **4**, cerebellum; **5**, medulla. **e**, eye; **fv**, first vertebra; **gpn**, glosso-pharyngeal nerve; **hn**, first spinal nerve; **ie**, internal ear; **no**, nasal opening; **on**, olfactory nerve; **os**, olfactory sacs; **p**, pneumogastric nerve; **sc**, spinal cord; **sv**, second vertebra; **t**, tympanum; **tn**, trigeminal nerve. (After Jammes.)

The *brain* is made up of three primary vesicles, a fore-brain, mid-brain, and hind-brain. The fore-brain gives rise to a pair of cerebral hemispheres (Fig. 147, *1*), the mid-brain to a pair of optic lobes (*3*), and the hind-brain to the cerebellum (*4*) and medulla oblongata (*5*). It is not certain what the functions of the cerebral hemispheres are in the frog; they are the seat of intelligence and voluntary control in higher animals. The brain as a whole controls the actions produced by the nerve centers of the spinal cord. "The higher centers of the brain are comparable to the captain of a steamer who issues orders to the man running the engine when to start and when to stop, and who has his hand on the wheel so as to guide the course of the vessel."

The ten pairs of nerves that arise from the brain of the frog are known as *cranial nerves*. Some of these are *sensory*, others *motor* in function. They are distributed to the nose (Fig. 147, *o.n*), eye, inner ear, skin and muscles of the face, muscles of the jaws, tongue, and pharynx, and to the throat, lungs, heart, stomach, and intestine. Many of the vertebrates possess two more pairs of cranial nerves than the frog.

The *spinal cord* is a thick tube directly connected with the brain (Fig. 147, *s.c*); it passes through the neural arches of the vertebral column. It is composed of a central mass of gray matter (Fig. 148, *g.m*), consisting mainly of nerve cells, and an outer mass of white matter (*w.m*) made up chiefly of nerve fibers.

The relation of the spinal nerves to the spinal cord and the paths taken by nervous impulses are indicated in Figure 148. There are ten pairs of spinal nerves in the frog. Each arises by a dorsal root (Fig. 148, *d.r*) and a ventral root (*v.r*) which spring from the horns of the gray matter of the cord. The two roots unite to form a trunk, which passes out between the arches of adjacent vertebræ.

The functions of nervous tissue are perception, conduction, and stimulation. These are usually performed by nerve cells, called *neurons*. The reflex is considered the physiological unit

of nervous activity. The apparatus required for a simple reflex in the body of a frog is shown in Figure 148. A sensory cell lying at the surface of the body (*s*) sends a fiber (*s.f*) into the spinal cord, where it branches out; these branches are in physiological continuity with branches from a motor cell (*v.c*) lying in the ganglion of the spinal cord. The motor cell (*v.c*) sends fibers (*m.f*) into a reacting organ, such as a muscle (*M*). These

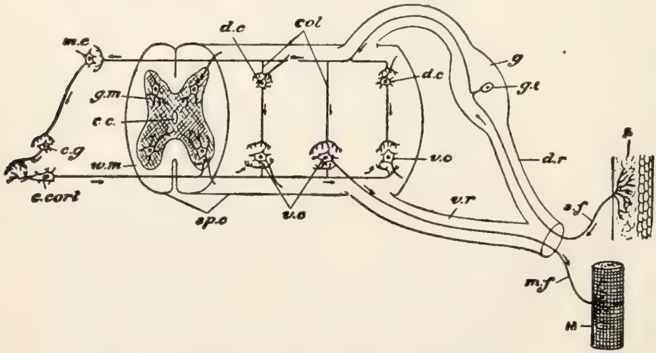

FIG. 148. — Diagram of the spinal cord showing the paths taken by nervous impulses. The direction of the impulses is indicated by arrows.

c.c, central canal; **col**, collateral fibers; **c.cort**, cell in the cerebral cortex; **c.g**, smaller cerebral cell; **d.c**, cells in dorsal horn of gray matter; **d.r**, dorsal root; **g**, ganglion of dorsal root; **g.c**, ganglion cell in dorsal ganglion; **g.m**, gray matter; **M**, muscle; **m.c**, cell in medulla oblongata; **m.f**, motor fiber; **S**, skin; **s.f**, sensory fiber; **sp.c**, spinal cord; **v.c**, cells in ventral horn of gray matter; **v.r**, ventral root; **w.m**, white matter. (After Parker.)

fibers extending to the reacting organ are called motor fibers (*m.f*); those leading to the spinal cord are termed sensory fibers (*s.f*). The sensory cell or *receptor* receives the stimulus and produces the nerve impulse; the motor cell, the *adjustor*, receives, directs, and modifies the impulse; and the muscle or other organ stimulated to activity is the *effector*. Within the spinal cord are association cells (*c.d*) whose fibers serve to connect structures within one ganglion or two succeeding ganglia.

The SYMPATHETIC SYSTEM consists of two principal trunks, which lie one on either side of the vertebral column. The nerves

of the sympathetic system are distributed to the internal organs which are thus intimately connected.

Sense Organs. — The principal sense organs of the frog are the eyes, ears, and olfactory organs. Certain structures on the surface of the tongue, and on the floor and roof of the mouth, probably function as organs of taste, and the many sensory nerve endings in the skin receive contact, chemical, temperature, and light stimuli.

The *nasal cavities* (Fig. 147, *o.s*) are supplied by the olfactory nerves (*o.n*) which extend from the olfactory lobe of the brain. The importance of the sense of smell in the life of the frog is not known.

There is no *external ear* in the frog. The *inner ear* (Fig. 147, *i.e*) lies within the auditory capsule, and is supplied by branches of the auditory nerve. The middle ear is a cavity which communicates with the mouth cavity through the Eustachian tube, and is closed externally by the tympanic membrane (*t*).

The vibrations of the tympanic membrane produced by sound waves are transmitted to the inner ear through a rod, the columella. The sensory end organs of the auditory nerve are stimulated by the vibrations, and the impulses carried to the brain give rise to the sensation of sound. The inner ears serve also as organs of equilibration. Frogs from which they are removed cannot maintain an upright position.

The *eyes* of the frog resemble those of man in general structure and function (Fig. 147, *e*), but differ in certain details. The eyeballs lie in cavities (orbits, Fig. 145) in the sides of the head. They may be rotated by six muscles (Fig. 147) and also pulled into the orbit. The upper eyelid does not move independently. The lower *eyelid* consists of the lower eyelid proper fused with the third eyelid or nictitating membrane. The *lens* is large and almost spherical. It cannot be changed in form nor in position, and is therefore fitted for viewing distinctly objects at a certain definite distance. Movements are noted much oftener than form. The amount of light that enters the eye can be regulated

by the contraction of the *pupil*. The *retina* of the eye is stimulated by the rays of light which pass through the pupil, and the impulses which are carried through the optic nerve to the brain give rise to sensations of sight.

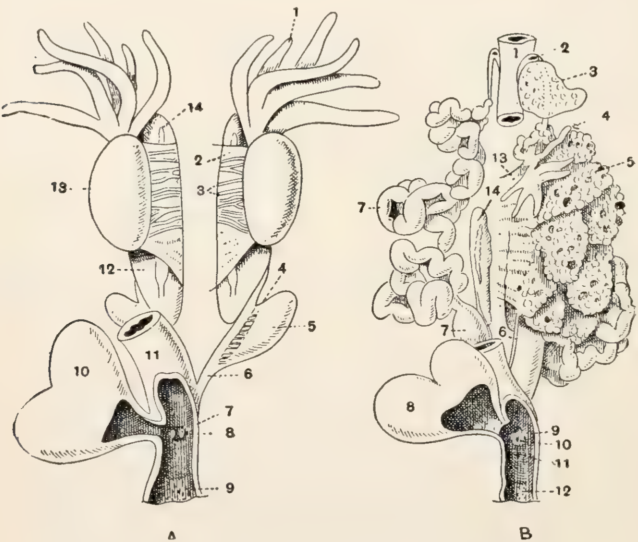

FIG. 149. — Urinogenital organs of the frog.

A, male. **1**, fat body; **2**, mesentery; **3**, efferent ducts of testis; **4**, ducts of seminal vesicle; **5**, seminal vesicle; **6**, archinephric duct; **7**, cloaca; **8**, orifice of ureter; **9**, proctodeum; **10**, allantoic bladder; **11**, rectum; **12**, kidney; **13**, testis; **14**, adrenal body.

B, **female**. **1**, œsophagus; **2**, mouth of oviduct; **3**, left lung; **4**, fat body; **5**, left ovary; **6**, archinephric duct; **7**, oviduct; **8**, allantoic bladder; **9**, cloaca; **10**, aperture of oviduct; **11**, aperture of archinephric duct; **12**, proctodeum; **13**, mesentery; **14**, kidney. (After Howes.)

Reproduction. — With one or two possible exceptions all vertebrates are *bisexual*. Individuals differ regarding their sex, being either males or females, instead of being all of one sort like the earthworm which is *hermaphroditic* and contains reproductive organs of both sexes. The male frogs can be distinguished from the females externally by the greater thickening of the inner

digit of their fore legs. The sex organs within the bodies of the two sexes are very different; they are essentially like those in all other vertebrates including man.

The germ cells of the male, the *spermatozoa*, arise in two oval organs, the *testes* (Fig. 149, A, *13*). When mature, they pass

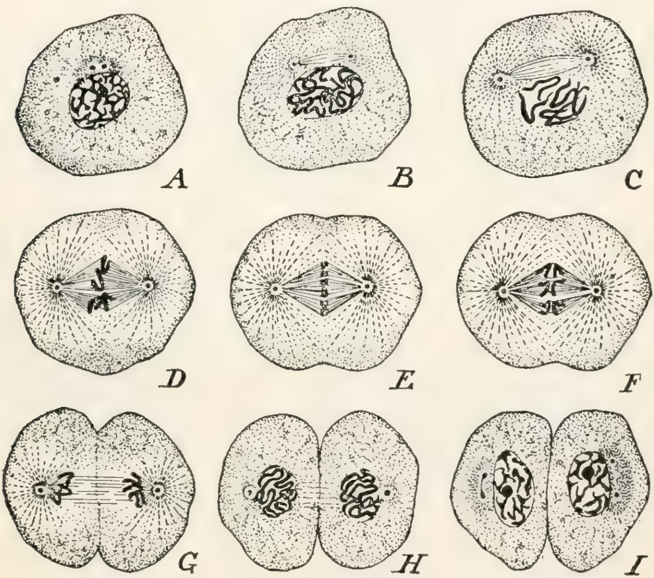

FIG. 150. — Diagrams representing the essential phenomena of mitosis.

A, a cell with resting nucleus; **B**, the centrosomes are separating; the chromatin forms a convoluted thread or spireme; **C**, the spireme is broken up into a number of V-shaped chromosomes; **D**, the chromosomes are arranged at the equator of the spindle; **E**, division of the chromosomes; **F**, divergence of the chromosomes; **G**, chromosomes collecting at the poles of the spindle; commencement of division of the cell body; **H**, **I**, complete division of the cell, and reconstitution of the nuclei. (From Bourne.)

through tubules (*3*) into the kidney (*12*) and from there through the kidney ducts, the ureters, to the seminal vesicle (*5*), where they are stored until the eggs of the female are ready to be fertilized. Then they pass out through the anal opening.

The *eggs* arise in the two ovaries of the female (Fig. 149, B, 5), make their way into a pair of tubes, the oviducts (7), and from there into the distensible uterus. Here they remain until they are ready to be laid, when they pass out through the anal opening.

EGG LAYING. — The eggs of the frog are laid in water in the spring. As soon as they emerge from the female they are fertilized by spermatozoa poured over them by the male. Then

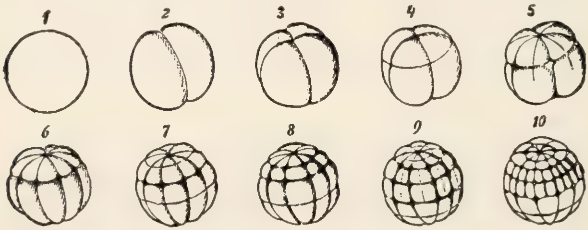

FIG. 151. — Stages in the early development of the frog's egg. (From Ecker.)

the jelly which surrounds them swells in the water and effectively protects them from injury.

EMBRYOLOGY. — The development of the egg which takes place within this coat of jelly is known as embryology and the partially developed egg is an *embryo*. One of the most remarkable of all natural phenomena is the development of a complex adult animal from an apparently simple egg. To understand how this takes place we must study the changes that go on within the egg.

When laid, the egg is a single cell. The spermatozoon is also a single cell. These two cells unite in *fertilization* and become fused into one. The nucleus of the egg and the nucleus of the spermatozoon approach each other and also fuse into a single nucleus.

The single cell thus formed, the *fertilized egg*, now proceeds to divide into two cells. Inside of the egg the single nucleus divides, by a process called mitosis, into two. During mitosis (Fig.

150) the nuclear wall breaks down, a spindle-shaped structure of threads with a starlike aster at each end is formed, and the principal nuclear substance, called chromatin, forms a certain number of rodlike bodies, the chromosomes (Fig. 150, A–D). The chromosomes split and one half of each is drawn to either end

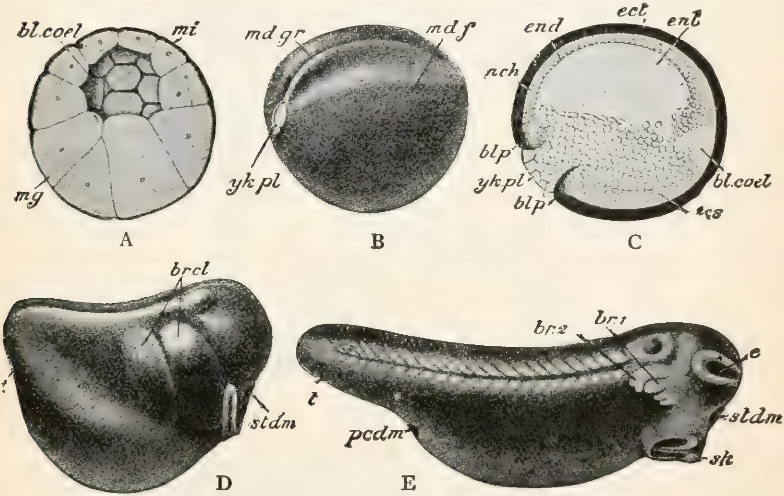

FIG. 152. — Development of the embryo of the frog.

A. Section of blastula. **bl.cœl**, blastocœl; **mi**, micromeres; **mg**, macromeres.

B. Formation of medullary groove, **md.gr**, and medullary fold, **md.f**; **yk.pl**, yolk-plug.

C. Section of egg in stage **B** to show germ-layers. **bl.cœl**, blastocœl; **blp**, blastopore; **ect**, ectoderm; **end**, entoderm; **ent**, enteron; **mes**, mesoderm; **nch**, notochord; **yk.pl**, yolk-plug.

D. Older embryo. **br.cl**, branchial arches; **stdm**, stomodæum; **t**, tail.

E. Newly hatched tadpole. **br.1**, **br.2**, gills; **e**, eye; **pcdm**, proctodæum; **sk**, sucker; **stdm**, stomodæum; **t**, tail. (From Parker and Haswell.)

of the spindle (E, F, G). Each group of chromosomes then becomes the center of a new nucleus (H, I). In this way the single nucleus forms two.

Externally a constriction appears around the diameter of the egg and the egg is pinched into two equal parts which remain

fastened together. Each of these two cells is provided with one of the two nuclei formed by the division of the single original nucleus. This first cell division is followed by the division of each of the two cells, as shown in the figure (Fig. 151). The

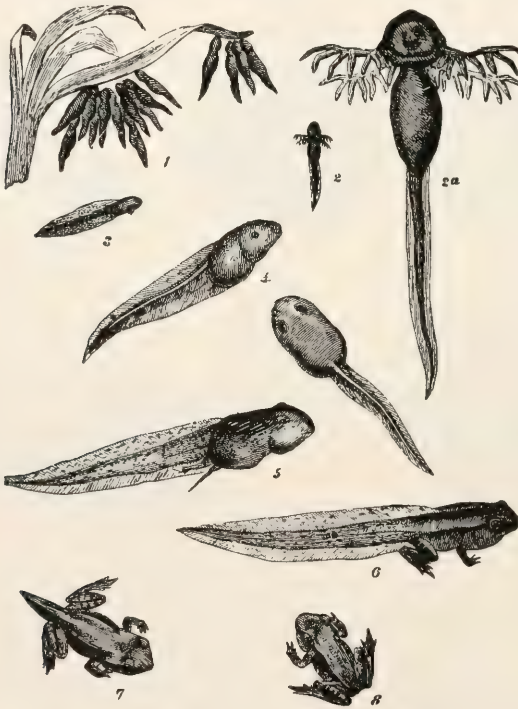

FIG. 153. — Stages in the growth and metamorphosis of the frog tadpole. (From Mivart.)

cells divide again and again until there are hundreds of cells in the egg.

These cells become arranged in layers, an outer layer, the *ectoderm* (Fig. 152, C, *ect*), an inner layer, the *entoderm* (*ent*), and a middle layer, the *mesoderm* (*mes*). The cells in each layer differ from those in the others both in their appearance and in

their history, and since the layers are the germs which give rise to the organs of the body, they are called *germ layers*.

This embryo moves about within the egg by means of cilia, but these soon disappear after hatching. The tadpole, after breaking out of the egg, lives for a few days on the yolk in its alimentary canal, and then feeds on algæ and other vegetable matter. The external gills grow out into long, branching tufts (Fig. 153, *2a*). Four pairs of internal gills are formed later, and when the external gills disappear, these function in their stead, the water entering the mouth, passing through the gill slits, and out of an opening on the left side of the body, called the spiracle.

The hind limbs appear first (Fig. 153, *5*). Later the fore limbs break out (*6*). The tail decreases in size as the end of the larval period approaches (*7*) and is gradually resorbed. The gills are likewise resorbed, and the lungs develop to take their place as respiratory organs. Finally the form resembling that of the adult frog is acquired (*8*).

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CHAPTER XXVIII

THE LAMPREY EELS AND OTHER CYCLOSTOMES

THE phylum PISCES which contains the fishes may be divided into four subclasses as follows: —

Subclass 1. CYCLOSTOMATA. — Lamprey Eels and Hagfishes.

Subclass 2. ELASMOBRANCHII. — Sharks and Rays.

Subclass 3. TELEOSTOMI. — True Fishes.

Subclass 4. DIPNOI — Lungfishes.

The simplest group of fishlike animals are the lamprey eels and hagfishes. These animals are very seldom seen, since they are aquatic and most of them live in the sea. The species most easily obtained for study in the laboratory is the sea lamprey (Fig. 138, A). This fishlike creature inhabits the waters along the Atlantic coast of North America, the coasts of Europe, and the west coast of Africa. It swims about near the bottom by undulations of its body, or when in a strong current, progesses by darting suddenly forward and attaching itself to a rock by means of its suctorial mouth. In the spring it ascends the rivers to spawn.

Form of Body. — The body of the lamprey reaches a length of three feet. The skin is not protected by an exoskeleton such as the scales of the true fishes, but is covered with slimy secretions from the numerous glands embedded in it. As an aid in swimming the posterior part of the body is provided with a tail fin and two dorsal fins.

Mouth and Food. — One of the most striking features of the lamprey is its circular, suckerlike mouth, devoid of jaws (Fig. 154). At the bottom of this sucker is a pistonlike tongue which when drawn in creates a partial vacuum, enabling the animal to

attach itself to solid objects. On and around the tongue are horny teeth used for rasping the food. Lampreys are parasites, living on the blood of other animals, principally fish. They make a hole in the victim's body and suck out the blood.

Respiration. — Lampreys breathe in the water by means of gills. There are seven pairs of circular respiratory openings just back of the eyes (Fig. 138, A); each opening is the entrance to a sac in which the gills are situated. Water enters and is forced out through the same openings, and, as in the crayfish, the blood in the gill filaments exchanges its load of carbon dioxide for a fresh supply of oxygen that is mixed with the water.

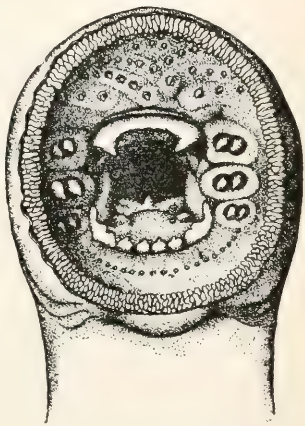

Fig. 154. — The mouth of the lamprey eel. (From Forbes.)

Sensations. — Lampreys are able to see, hear, smell, taste, and feel, but none of their senses is very highly developed. The eyes are poor; the ears have only two semicircular canals instead of the usual three; there is a single nostril situated on top of the head between the eyes; and a few taste cells inside the pharynx.

Internal Organs. — The internal organs are likewise primitive. The *skeleton* is entirely of cartilage; there is no distinct *stomach;* the *heart* has only one auricle and one ventricle; and the *brain* is very simple, resembling that of the embryo of higher vertebrates.

Development. — The development of the lamprey is very interesting. The eggs produce larvæ which differ in many respects from the adult, and were at one time considered a distinct species of animal. The larvæ lie buried in mud and sand, and food particles are drawn into the mouth by means of a current of water produced by cilia. In the winter of the third or

fourth year the larval lamprey undergoes a metamorphosis, during which the structure and habits of the adult are acquired.

Other Cyclostomes. — The other lampreys and the hagfishes resemble the sea lamprey in most respects. They live in the mud of the sea bottom and are of considerable economic importance because of their parasitic habits. All kinds of fish are attacked by them, but principally shad, sturgeon, cod, mackerel, and flounders. A hole is rasped through the body wall just beneath the pectoral fins and the blood sucked out. Lampreys are used as food by man, but they are not numerous enough to be of any great value.

The Brook Lamprey. — In many of the North American brooks lives a very small brook lamprey, but since the adults probably eat no food and the young live on minute animals and plants, they are of no economic importance. However, if they can be caught, they can be kept alive in the laboratory for a long time and thus furnish excellent material for study.

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CHAPTER XXIX

THE STRUCTURE AND ACTIVITIES OF FISHES

FISHES are rather easy to study since specimens can be obtained in fish markets for examination in the laboratory. The common **perch** is perhaps the best species because of its conven-

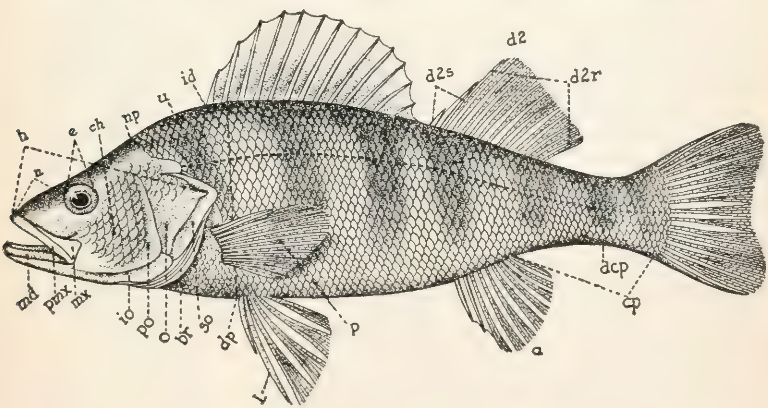


FIG. 155. — Diagram of a fish (perch) with parts named.

a, anal fin; **br**, branchiostegal rays; **ch**, cheek; **cp**, caudal peduncle; **d1**, spinous dorsal fin; **d2**, soft dorsal fin; **d2r**, rays of second dorsal fin; **d2s**, spines of second dorsal fin; **dcp**, depth of caudal peduncle; **dp**, depth (of body); **e**, eye; **id**, insertion of dorsal fin; **io**, interopercle; **md**, lower jaw, or mandible; **mx**, maxillary; **n**, nose, or snout; **np**, nape; **o**, opercle; **p**, pectoral fin; **pmx**, premaxillary; **po**, preopercle; **so**, subopercle; **v**, ventral fin. (After Forbes.)

ient size and general distribution. Every one who has ever had the opportunity has "gone fishing," and knows something about the differences between different species. A great many peculiar fishes, however, live in the sea or are confined to restricted parts

of the world, so that they are very seldom seen. The general needs of fishes and methods of supplying them may be discussed to advantage with the perch as a basis (Fig. 155).

Habitat. — Fishes are all *aquatic*. Some of them are restricted to the salt water of the sea, others to fresh water, and a very few are, like the salmon, able to swim from the sea into fresh water or from fresh water into the sea without suffering any injury.

FIG. 156. — Front view of a fish (Spanish mackerel). (From Dean.)

Form of Body. — Since the water offers more resistance than air to movement through it, and since fish as a rule must move rapidly to catch their food and escape their enemies, it is not strange that the fish's body is long and slender, pointed at the ends, and compressed from side to side. This form offers very little resistance to the water (Fig. 156). Variations in form depend upon the habits of the fish. For example, the flatfishes, or flounders (Fig. 171), have thin bodies which adapt them for life on the sea bottom; the eels (Fig. 165, D) have a long, cylindrical body which enables them to enter holes and crevices, and the porcupine fish possesses a covering of heavy spines which stick straight out when it inflates itself and protect it from its enemies.

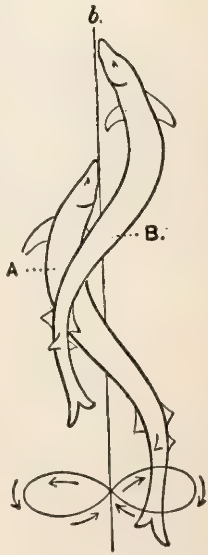


FIG. 157.—Diagram showing how the tail of a fish is used in swimming. (After Pettigrew.)

Locomotion. — The principal locomotor organ is the tail, which is lashed from one side to the other, forcing the fish ahead, much as a boat is propelled by sculling or a steamer by its screw (Fig. 157). The tail is made more effective by the presence of the caudal fin, which offers more resistance to

the water. The other fins aid the fish in maintaining an upright position and help it to steer the body up or down, straight ahead, or from one side to the other.

The shapes and positions of the fins differ in different species; for example, the caudal fin of the perch (Fig. 155) is bilaterally symmetrical and is adapted to swimming straight ahead, whereas that of the sturgeon (Fig. 163, A) is longer above than below and tends to force the body downward to the bottom, where this species obtains its food.

Fishes may often be seen suspended in the water and almost motionless. This they are able to do because of the presence

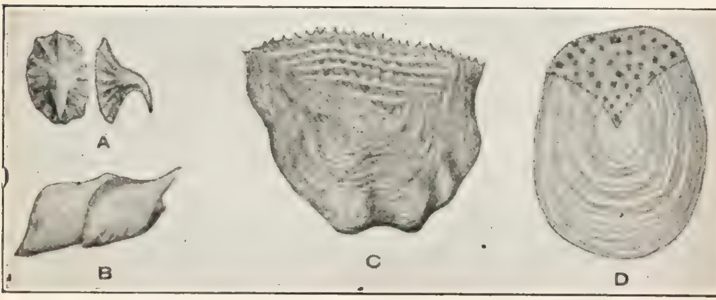


FIG. 158. — Fish scales.

A, placoid; **B**, ganoid; **C**, ctenoid; **D**, cycloid. (From Parker and Haswell.)

of an air bladder within the body which decreases their weight until they are exactly as heavy as the amount of water they displace.

Protection. — The enemies of the adult fish are principally other fish, birds such as kingfishers, herons, gulls, and terns, and flesh-eating mammals like the otter. From most of these the fish escape by swimming away rapidly, but from ordinary physical injury they are protected by an exoskeleton of scales or bony plates.

SCALES. — The scales are of several kinds; those most commonly seen are thin, oval structures (Fig. 158, C and D) which

are arranged in oblique rows on the fish's body and overlap each other like the shingles on the roof of a house (Fig. 155). In such fish as the gar pike (Fig. 163, C) the scales are very thick and strong and diamond-shaped (Fig. 158, B); very few animals are able to penetrate such an armor. Sharks and rays (Figs. 161 and 162) possess a covering of toothlike scales (Fig. 158, A), which actually develop into teeth in the mouth region. The spines of some fishes develop from scales, and bony plates such as those of the sturgeon (Fig. 163, A) have a similar origin.

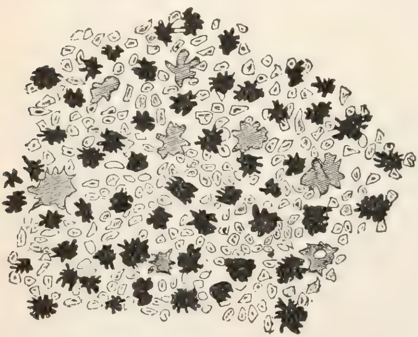


Fig. 159. — Pigment bodies in the skin of a fish. (After Cunningham.)

Color. — The colors of the fish are more important as a protection than the scales since they tend to conceal the animal amid its surroundings. The red, orange, yellow, and black pigments present in the skin (Fig. 159) may give the fish these colors or else blend to form other colors. The structure of the scales may also produce certain colors due to reflection and iridescence.

Usually the colors are arranged in a definite pattern consisting of transverse or longitudinal stripes and spots of various sizes. Coral-reef fishes have long been famous for their brilliant colors, and many fresh-water fishes of the temperate zone exhibit bright hues distributed so as to form striking and intricate patterns (*e.g.* the rainbow darter). A few fish are able to change their colors so as to match the bottom on which they lie; this is true of the flounder (Fig. 171).

Sensations. — Fishes possess all of the five senses, but the sense organs differ somewhat from those of land animals.

The *eyes* (Fig. 155, *e*) are usually without lids, since the water keeps the eyeball moist and free from foreign matter. The pupil

is large so as to allow more light to enter — a necessity under water where the light is not strong. Fishes probably cannot see in the air.

There is no outer or middle *ear*, but only the membranous labyrinth is present, since the water transmits the sound waves directly to the inner ear.

Unlike the lamprey eel, there are two *nostrils* in the fishes, each of which is a sac connected with the water through a pair of openings in front of each eye, and containing many sense cells of smell in their walls.

The sense of *taste* is not well developed. Fishes swallow their food whole or in large pieces, and a few sense cells that are present in the walls of the mouth are sufficient.

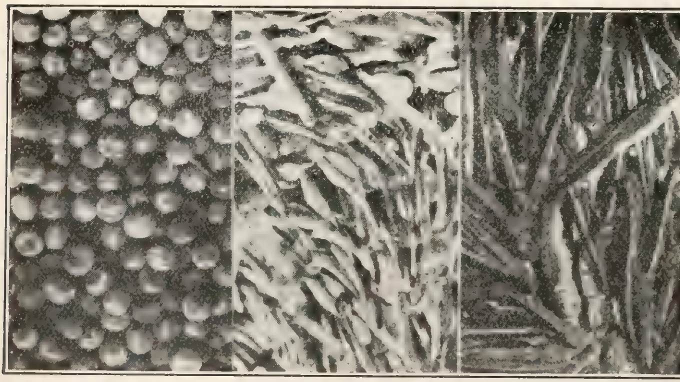
The entire skin, but especially that of the lips, is provided with *tactile* sense cells.

Respiration. — Respiration in fishes is typically aquatic, taking place in the *gills*. In a few fish the *air bladder* may also serve as a respiratory organ. The sharks (Fig. 161) possess rows of gill slits on either side of the head, but in most fishes the gills are protected from injury by a gill cover, the operculum (Fig. 155, *o*).

The four pairs of gills usually present are supported by four pairs of *gill arches*. Each gill bears a double row of *branchial filaments* which are abundantly supplied with capillaries. The afferent branchial artery brings the blood from the heart to the gill filaments; here an exchange of gases takes place. The carbonic acid gas with which the blood is loaded passes out of the gill, and a supply of oxygen is taken in from the continuous stream of water which enters the pharynx through the mouth and bathes the gills on its way out through the gill slits. Because oxygen is taken up by the capillaries of the gill filaments, a constant supply of fresh water is necessary for the life of the fish. If the fish is deprived of water entirely, respiration is prevented, and the fish dies of suffocation.

Reproduction. — As in the frog, the *eggs* of most fish (Fig. 160, A) are deposited in the water by the female fish and then

fertilized by the *spermatozoa* (milt) of the male which are poured over them. At this time the fish are said to be *spawning*. Very few of the eggs succeed in producing adult fish, since they are eaten by numerous animals and destroyed by fungous plants and by being smothered by sand and mud on the bottom. The young fish lives for a time on the yolk stored up in the egg (Fig. 160, B); later it begins to feed on small crustaceans and insects



A B C

FIG. 160. — Photographs of three stages in the growth of the trout. (From Bul. U. S. Fish Com.)

(Fig. 160, C), and finally on larger crustaceans, insects, mollusks, and other fish.

Many fish *migrate* long distances to lay their eggs. For example the *chinook salmon* (Fig. 172, D) lives in the sea along the Pacific coast from Monterey Bay, California, and China, north to Bering Straits. It enters the fresh-water streams to spawn, especially the Sacramento, Columbia, and Yukon rivers. The ascent takes place in the spring and summer, beginning in February or March in the Columbia River. The salmon do not feed during this migration, but swim at first slowly and then more rapidly until they reach the small, clear mountain streams often more than a thousand miles from the sea. Spawning

occurs from July to December, according to the temperature of the water, which apparently must be below 54° Fahrenheit. The eggs are deposited upon the gravelly bottoms of the streams, after which both males and females die; consequently an individual spawns only once in its lifetime. The eggs hatch in about seven weeks, and the young remain on the spawning ground for six weeks. They then float slowly downstream and may be four or five inches long when they reach the sea.

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CHAPTER XXX

SOME COMMON FISHES OF NORTH AMERICA

Subclass 2. Elasmobranchii

THE *sharks* (Fig. 161) and *rays* (Fig. 162) are characterized by a cartilaginous skeleton, toothlike scales (Fig. 158, A), a slitlike mouth on the ventral side of the head, and gill openings not covered by an operculum. The sharks resemble the true fish in shape, whereas the rays are very much flattened. Sharks

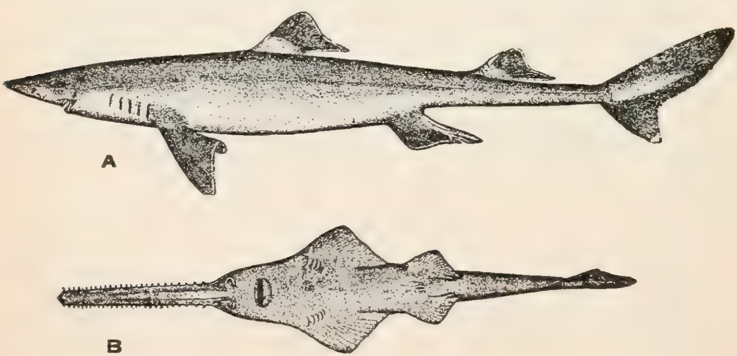

FIG. 161. — **A**, dogfish shark; **B**, sawfish. (After Goode.)

are usually less than ten feet long and, contrary to general belief, feed upon crustaceans, squids, and fish rather than upon human beings. Occasionally the great white shark which lives in the tropics and reaches a length of thirty feet may become a man eater.

The *rays* or *skates* have their bodies greatly flattened and are thus adapted to a life on the bottom. The *sting ray* (Fig. 162)

occurs off the coast of Florida. Its name is derived from the sting inflicted by a spine at the base of its whiplike tail. The *sawfish* (Fig. 161, B) is a ray with its head extending forward as a long, sawlike projection. The saw of a fifteen-foot fish is about five feet long; it is used to defend the fish or to capture its food. The *torpedo ray* possesses electric organs on either side of its head which can give a shock strong enough to stop rather large animals.

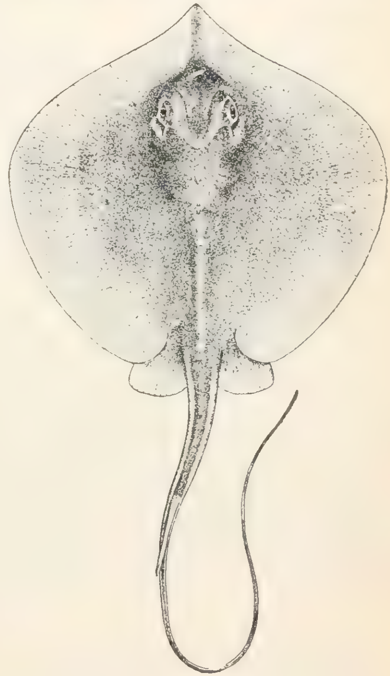

FIG. 162. — Sting ray. (From Jordan and Evermann.)

Subclass 3. Teleostomi

The *true fishes* or TELEOSTOMI have a skeleton consisting entirely or partly of bone and an operculum covering the gills. About twelve thousand species are known from the entire world and over three thousand species occur in North America.

The *sturgeon* (Fig. 163, A) is a rather primitive fish that resembles a shark in the shape of the body. Its tail fin is larger above and its mouth is on the ventral surface. It feeds on the bottom, using its snout for stirring up the mud and the sensitive filaments (barbels) near the mouth for finding food. Sturgeons are economically important; their flesh is excellent for food; their eggs are made into a much-prized table delicacy called caviar; and their air bladders are used as isinglass.

A near relative of the sturgeon is the *paddlefish* (Fig. 163, B)

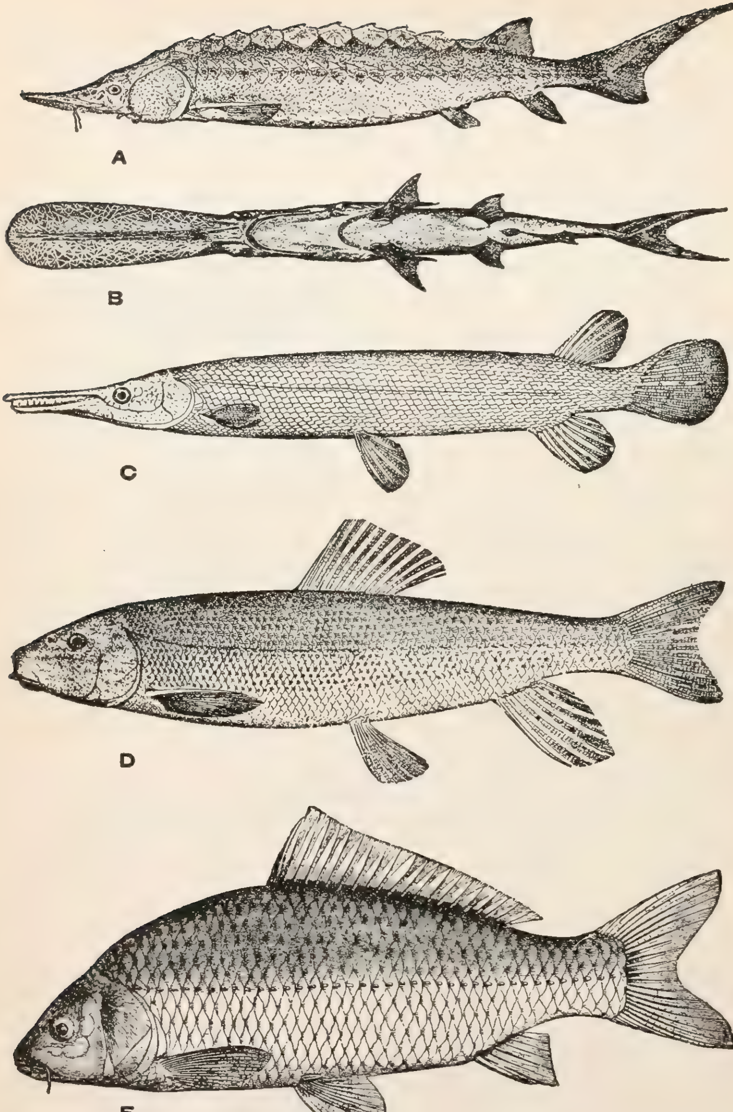

FIG. 163. — **A**, sturgeon; **B**, paddlefish; **C**, gar pike; **D**, sucker; **E**, carp. (From Goode.)

which lives in the rivers of the Mississippi Valley. This peculiar fish reaches a length of six feet and a weight of one hundred and sixty pounds, but the specimens usually taken weigh no more than fifty pounds. Its large, paddle-shaped snout is regarded as a sense organ, and its use is still unknown. The food of the paddlefish consists largely of minute plants and animals, of which enormous numbers are devoured. The paddlefish is good to eat, but its roe (eggs), from which caviar is made, is more valuable than its flesh.

The *gar pike* (Fig. 163, C) is another primitive fish that looks very much like the fossil remains of ancient fish sometimes found

FIG. 164. — Photograph of a catfish. (From Shufeldt.)

in the earth's crust. It has a remarkably strong armor of scales and a long snout fitted with formidable teeth. The fishing industry is injured by gar pikes which kill great numbers of valuable fish, especially the young.

The *suckers* (Fig. 163, D) are very abundant in many North American streams. Their lips are protractile and fleshy, being used for obtaining worms, insects, etc., from the bottom. Suckers are not considered very good to eat, but because of their abundance are of considerable economic importance.

The *German carp* (Fig. 163, E) has become established in many parts of the country since it was introduced in 1872. It is able to live in muddy water, breeds rapidly, and will eat almost any-

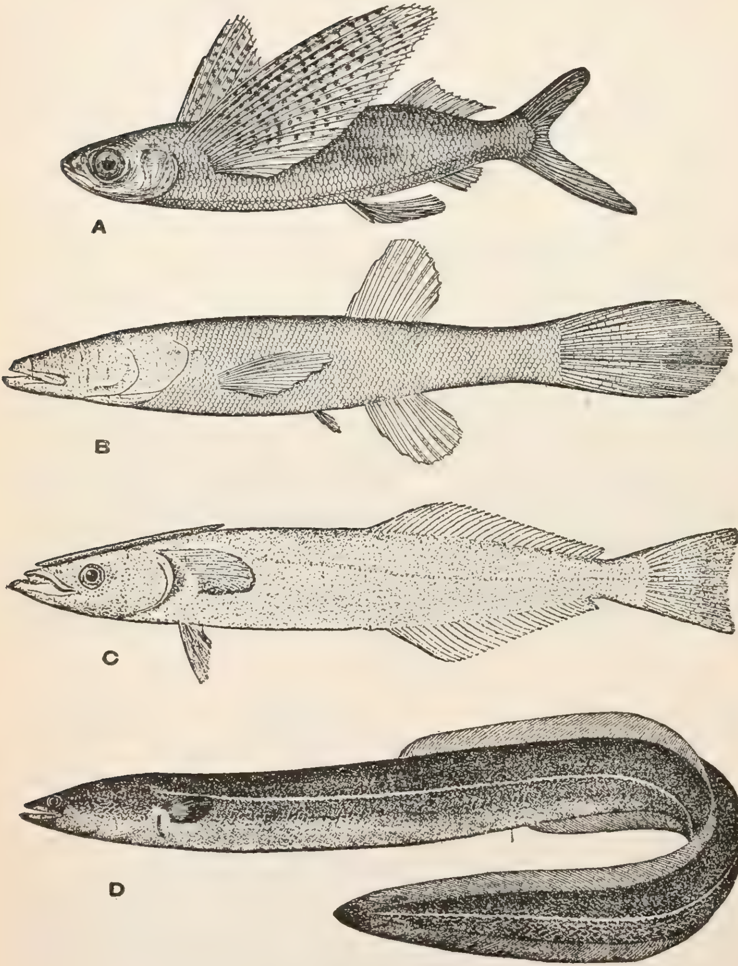

FIG. 165. — **A**, flying fish; **B**, cave fish; **C**, remora; **D**, eel. (From Jordan and Evermann.)

thing. Carp are accused of destroying the eggs of other fishes, of driving other fishes away by stirring up mud, and of eating aquatic vegetation and thus depriving wild ducks of their food.

Catfishes (Fig. 164) are scaleless fish that, like the sturgeon, live on the bottom and find their food by means of sensitive filaments (barbels). The *bullhead* is a small catfish known to every fisherman. The *Mississippi catfish* sometimes reaches a length of five feet and a weight of over one hundred pounds. It is a valuable food fish.

A discussion of many of our *food and game fishes* will be found in the next chapter.

A few fish are worthy of space here because of their peculiarities. Some of the *cave fishes* (Fig. 165, B) found in the river Styx of the Mammoth Cave and in other subterranean streams are blind.

Certain species of fish living in warm seas have greatly enlarged pectoral fins (Fig. 165, A) which enable them to rise out of the water and "fly" for as much as an eighth of a mile.

The *true eels* (Fig. 165, D) have very long, cylindrical bodies shaped like that of the lamprey eel, with which they should not be confused.

The *sea horse* (Fig. 166) is a fish only a few inches long, with a head that reminds one of the head of a horse. It can cling to objects with its prehensile tail. The male protects the eggs in a brood pouch.

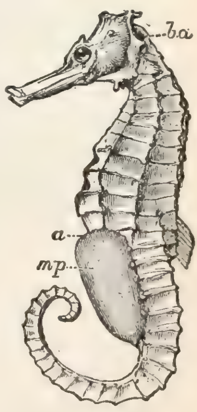

FIG. 166. — The sea horse. **a**, anus; **b.a**, branchial aperture; **m.p**, brood pouch. (From the Cambridge Natural History.)

The *remora* (Fig. 165, C) is a fish that clings to the body of a shark with its dorsal fin which is modified as a sucker; it thus secures transportation and possibly food when the shark has a meal.

In the *deep sea* are many fishes with phosphorescent organs distributed over the body; these may serve to illumine the sur-

roundings or to lure other fish within reach of the sharp teeth. When these fish are drawn up to the surface, the gas in the air bladder, being relieved of most of its pressure, expands and often forces part of the alimentary canal out of the mouth.

Subclass 4. Dipnoi

The third subclass of fishes contains the DIPNOI or *lungfishes* (Fig. 167). There are only five species of these alive at the present time. One occurs in Australia, three in Central Africa,

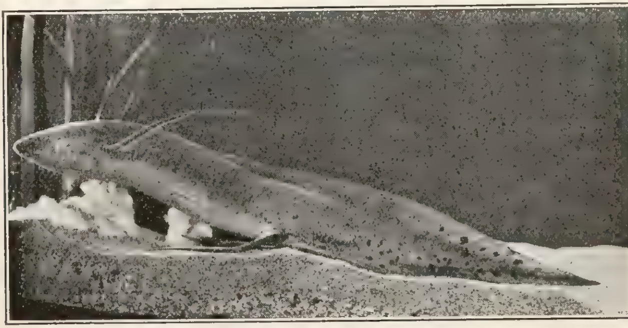

FIG. 167. — Photograph of a living African lungfish. (Photo. provided by American Museum of Natural History.)

and one in South America. All of them are able to live in marshes, swamps, and other bodies of stagnant water because their air bladders function as a lung. They are therefore not dependent upon fresh water, but can breathe air.

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See end of Chapter XXIX.

CHAPTER XXXI

THE RELATIONS OF FISH TO MAN

THE fishes constitute a group of animals that are practically always beneficial to man. Fish are caught sometimes for pleasure alone, as an exhilarating form of recreation; and the species that are fished for in this way are called *game fishes*. More often fish are caught as an article of food, and such are called the *food fishes*.

Game Fishes. — Every one is familiar with many of the fresh-water game fishes. Among the common species are the perches, trout, pike, muskallunge, and basses.

FRESH-WATER GAME FISHES. — The yellow perch (Fig. 155) inhabits the fresh-water streams and lakes of the northeastern United States, and ranges west to the Mississippi Valley. It is perhaps the best pan fish among American fresh-water fishes, and in many localities it is taken largely for market. It is not a good game fish, but for the food market it has one advantage — it is easy to catch. The perch has been introduced successfully into several small lakes in Washington, Oregon, and California. It can be artificially propagated, but other fish, such as whitefish, lake trout, and pike perch, are of greater commercial importance and are, therefore, preferred for propagative purposes to the yellow perch.

The *trout family* contains a number of our finest game fishes. The *brook* or *speckled trout* prefers clear, cool streams with a swift current and a gravelly bottom. The *mountain* or *cut-throat trout* is a large species inhabiting the streams and lakes of the Rocky Mountain region. The *rainbow trout* (Fig. 170, A) is also a western species. It is a good game fish and takes the

fly readily. In weight it averages about two or three pounds. The *steelhead* or *salmon trout* is found in the streams along the Pacific coast. Like the salmon it migrates upstream to spawn. Its average weight is about eight pounds. Thousands of steelhead trout are taken each year for canning purposes, especially in the Columbia River. They are also considered excellent game fish.

The *common pike* or *pickerel* (Fig. 168, A) inhabits all suitable fresh waters of northern North America, Europe, and Asia. It is

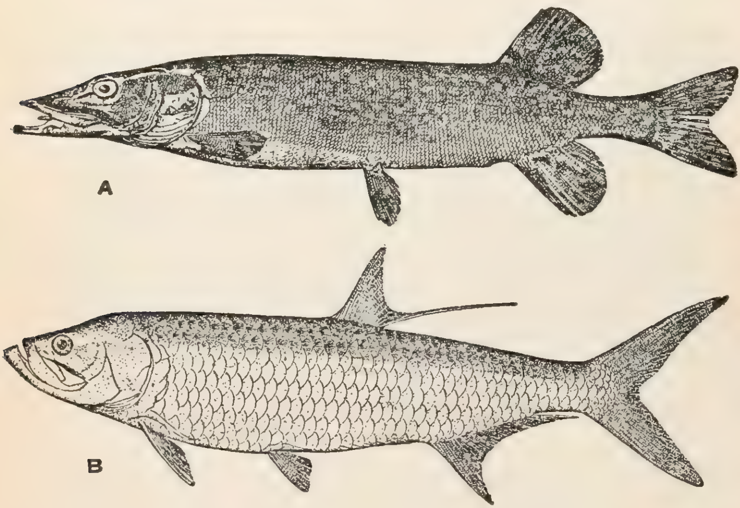

FIG. 168. — **A**, pike; **B**, tarpon. (From Goode.)

extremely voracious, feeding on other fishes, frogs, aquatic birds, and many other aquatic animals. The pike is an excellent game fish, but its flesh is not very good. The *muskallunge* resembles the pike in form and habits. It is found in the Great Lakes region and is a king among fresh-water game fishes, reaching a length of over seven feet and a weight of almost a hundred pounds.

The *bass family* comprises about thirty species, most of which are good game fishes and also excellent for the table. Some of

the most common species are the crappie, the rock bass, the bluegill, the common sunfish or pumpkin seed (Fig. 169), the small-mouthed black bass, and the large-mouthed black bass.

The *small-mouthed black bass* is considered " inch for inch and pound for pound, the gamest fish that swims." The male bass in May or June makes a nest by clearing away a place near shore

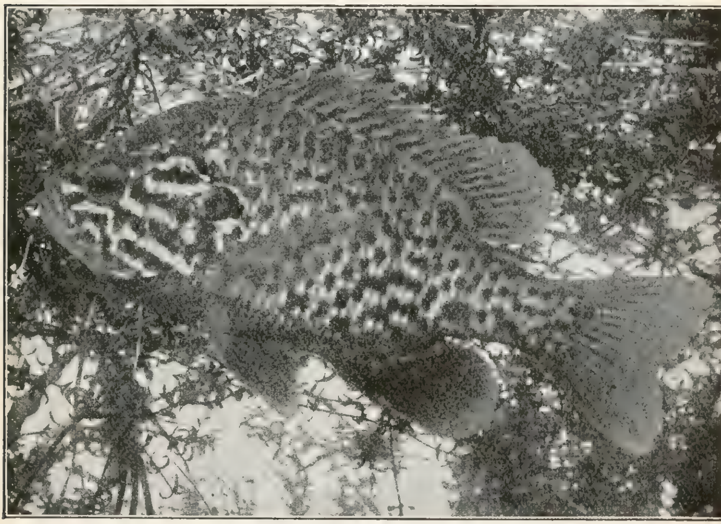

Fig. 169. — Photograph of a living sunfish. (After Shufeldt.)

where there are good-sized stones. Eggs are then laid and fertilized, and the male guards them during the hatching period of five or six days. The male continues to protect the young until they reach a length of an inch and a quarter. Black bass are successfully propagated in artificial ponds by the Bureau of Fisheries.

Salt-water Game Fishes. — Many salt-water fish also are caught principally for purposes of recreation. Among these are the tarpon, sea bass, and tuna. There are four or five species of tarpon inhabiting the tropical seas. The common tarpon

(Fig. 168, B) is a famous game fish on the coast of Florida, and is called the "silver king."

The *striped bass* is a fine game fish occurring along the coast of eastern North America. It has also been successfully introduced along the coast of California. The *jewfish* or *black sea bass* is the giant game fish of the California coast. It can be taken with a sixteen-ounce rod, and there are many records of specimens captured by this method weighing over three hundred pounds.

The *tuna* is called the tunny or horse mackerel on our eastern coast, but is the tuna of California. Tunas are eagerly sought with hook and line, and many that weighed over one hundred pounds have been landed by this means.

Food Fishes. — It is, of course, a matter of personal opinion as to which of the food fishes is the best. The value of a species does not depend upon its edible qualities, however, so much as upon its abundance. The *common herring* is the most important of the food fishes in the Atlantic. Herring swim about the North Atlantic in immense shoals, often covering half a dozen square miles and containing as many as three billion individuals. On the New England coast herring are smoked, salted, pickled, packed as sardines, or used for bait in codfishing.

Another group of important food fishes that occur in the sea belong to the *mackerel family*. Fifteen species of mackerel inhabit the salt waters of North America. The *common mackerel* (Fig. 170, B) occurs in the North Atlantic, swimming about in enormous schools. It feeds on small aquatic animals, such as *Crustacea*, and furnishes food for other fishes. It is also a valuable food fish for man. The *Spanish mackerel* is also a common food fish of the North Atlantic.

The *flounder family* contains flatfishes known as flounders (Fig. 171), halibuts, soles, plaice, and turbots. They are flattened from side to side, and thus adapted for life on the sea bottom. Frequently they are colored on the upper surface so as to resemble the sand or other material surrounding them.

The young flatfish resembles an ordinary fish when it hatches, but soon begins to broaden laterally and swim on its side, while the eye on the lower side moves around to the upper side. The

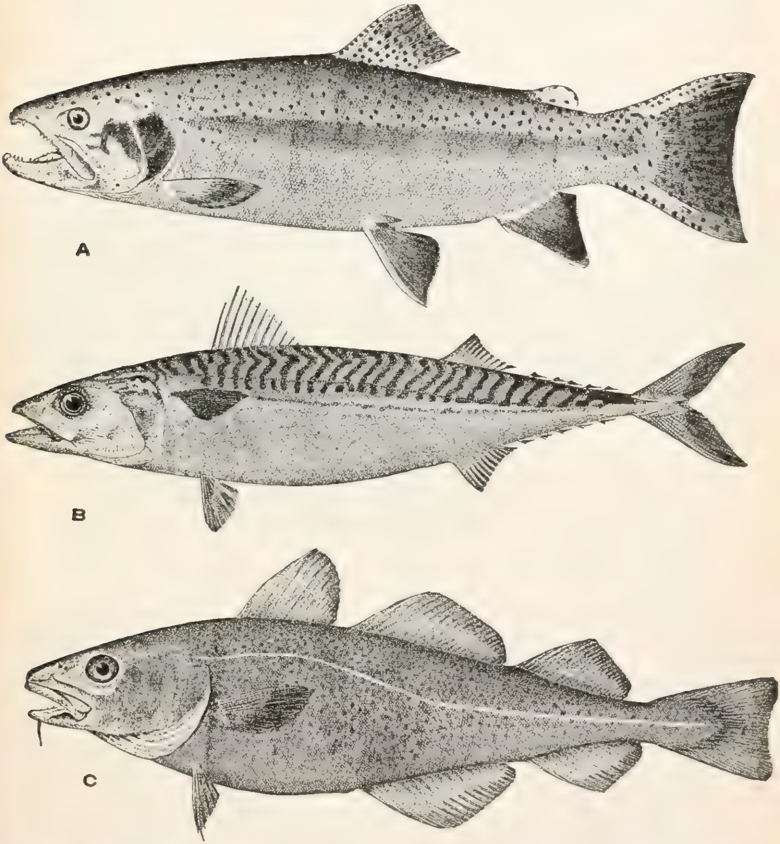

FIG. 170. — **A**, rainbow trout; **B**, mackerel; **C**, cod. (From U. S. Fish Manual.)

common halibut and the winter flounder are important American food fishes.

Many of our most important food fishes, the pollocks, codfishes, haddocks, and hakes, belong to the *codfish family*. "From

the earliest settlement of America the cod has been the most valuable of our Atlantic coast fishes. Indeed, the codfish of the Banks of Newfoundland was one of the principal inducements which led England to establish colonies in America." The total weight of the codfishes landed at Boston and Gloucester in 1908 was 41,615,277 pounds, valued at $1,042,683. The Bureau of Fisheries distributes millions of fry every year.

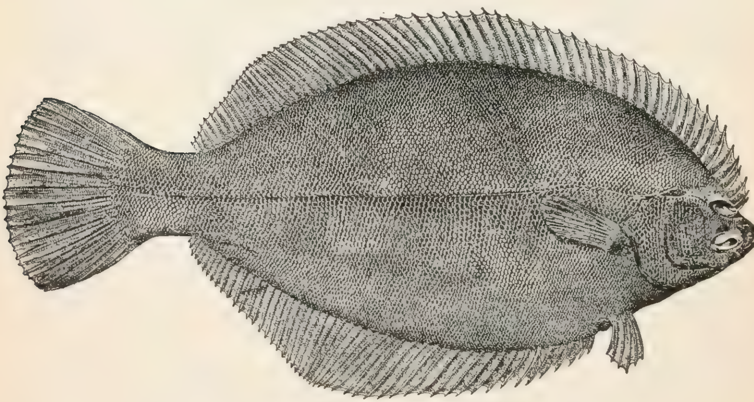

Fig. 171. — Flounder. (From U. S. Fish Manual.)

Fresh-water Food Fishes. — The food fishes mentioned thus far are all marine species. There are, however, a great many fresh-water fishes of commercial importance. Some of these are mentioned in Chapter XXX; namely, the sturgeons, paddle-fishes, suckers, carp, and catfishes. Others are the whitefish, lake trout, pike perch, and salmon.

The common *whitefish* (Fig. 172) occurs throughout the Great Lakes region. During the winter it prefers deep water, but in the spring it migrates to the shallow water to secure insect larvæ which become abundant at that time. It migrates to shallow water again in the autumn to spawn. The mouth is on the under side, and the crustaceans, mollusks, and other animals used as food are picked up from the bottom. The eggs are laid

over honeycomb rock, and since many of them are covered by sediment or fall prey to mud puppies, yellow perch, crayfishes, and other enemies, very few develop into adult fish. Because

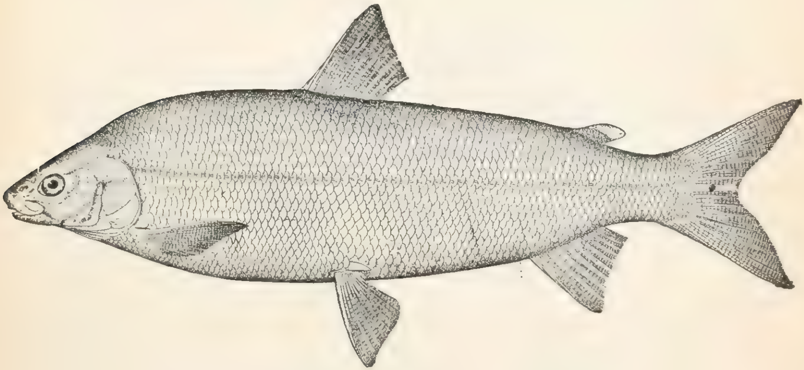

FIG. 172. — Whitefish. (From U. S. Fish Manual.)

of this fact the government each year gathers, rears, and distributes millions of whitefish eggs. Whitefishes are captured in deep water by means of gill nets which hold the fish just be-

FIG. 173. — Lake trout. (From U. S. Fish Manual.)

hind the gill covers. The average weight is about four pounds, but they may become as heavy as twenty pounds.

The *lake trout* (Fig. 173) is another important food fish of the Great Lakes region. It is the largest of our trouts, averag-

ing about eighteen pounds, but occasionally attaining a weight of over one hundred pounds. Lake trout are captured usually in gill nets. They are omnivorous, but show special preference for lake herring. The spawning season ranges from September

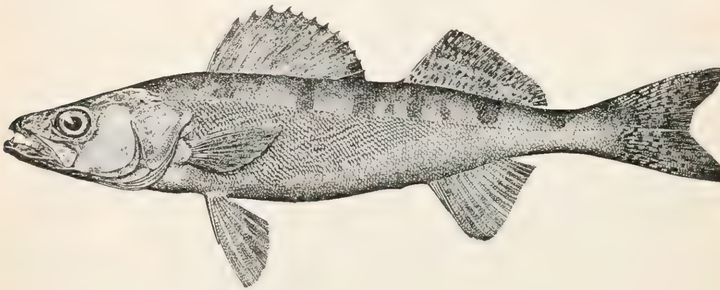

Fig. 174. — Pike perch. (From U. S. Fish Manual.)

to November, according to the latitude. Millions of eggs are cared for and distributed by the government each year.

The *wall-eyed pike* or *pike perch* (Fig. 174) is another well-known and valuable species. It is common in the Great Lakes region and is extensively propagated by the Bureau of Fisheries.

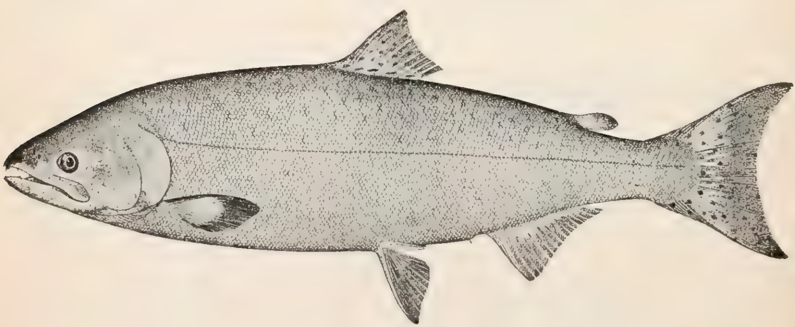

Fig. 175. — Salmon. (From U. S. Fish Manual.)

The Canning of Salmon. — Quite a number of species of salmon are used for purposes of canning, especially on the Pacific coast. "The canning of salmon, that is, the packing of the

flesh in tin cases, hermetically sealed after boiling, was begun on the Columbia River in 1866. In 1874 canneries were established on the Sacramento River, in 1876 on Puget Sound and on the Frazer River, and in 1878 in Alaska. At first only the quinnat salmon was packed; afterwards the red salmon and the silver salmon, and finally the humpback, known commercially as pink salmon.

"The output of the salmon fishery of the Pacific coast amounts to about fifteen millions per year, that of Alaska constituting seven to nine millions of this amount. Of this amount the red salmon constitutes somewhat more than half, the quinnat about four fifths of the rest.

"In almost all salmon streams there is evidence of considerable diminution in numbers, although the evidence is sometimes conflicting. In Alaska this has been due to the vicious custom, now done away with, of barricading the streams so that the fish could not reach the spawning grounds, but might all be taken with the net. In the Columbia River the reduction in numbers is mainly due to stationary traps and salmon wheels, which leave the fish relatively little chance to reach the spawning grounds. In years of high water doubtless many salmon run in the spring which might otherwise have waited until fall.

"The key to the situation lies in the artificial propagation of salmon by means of well-ordered hatcheries. By this means the fisheries of the Sacramento have been fully restored, those of the Columbia approximately maintained, and a hopeful beginning has been made in hatching red salmon in Alaska" (Jordan).

The Value of the Fishing Industry. — The value of the fishing industry may be judged from statistics obtained at Boston and Gloucester, where about seven eighths of all the fish captured offshore along the Atlantic coast are brought by the fishermen. During the calendar year, 1908, 181,465,000 pounds of fish, worth to the fishermen $4,629,000, were landed at these two cities. The most important species were the cod, haddock, hake, pollock, halibut, and mackerel. The salmon fisheries of Alaska are

even more valuable. The total quantity taken in 1908 was 198,952,814 pounds, valued at $10,683,051. Fifty canneries and forty salting establishments were operated, and 12,183 persons were employed to catch, prepare, and transport the canned, pickled, fresh, and frozen fish.

SOME OF THE FISH AND EGGS DISTRIBUTED BY U. S. BUREAU OF FISHERIES FROM JUNE 30, 1908, TO JUNE 30, 1909

Species	Eggs	Fry[1]	Fingerlings[2]	Total
1. Flatfish		786,626,000		786,626,000
2. Pike perch	457,850,000	187,050,000		644,900,000
3. Whitefish	142,220,000	277,445,000		419,665,000
4. White perch	24,500,000	318,760,000	2,650	343,262,650
5. Yellow perch	10,000,000	213,610,410	50,873	223,661,283
6. Cod		153,536,000		153,536,000
7. Blueback salmon	100,000	93,409,496		93,509,496
8. Lake trout	22,806,000	27,188,177	1,345,100	51,339,277
9. Brook trout	905,000	5,821,322	3,723,489	10,449,811
10. Rainbow trout	286,150	292,408	2,026,463	2,605,021
11. Large-mouth black bass		32,500	540,962	573,462
12. Small-mouth black bass		262,674	111,924	374,598

The Artificial Propagation of Fishes. — In many places the fish have been captured in such great numbers that laws regulating the fishing industry have been passed. The federal and state governments have also for many years operated fish hatcheries, where the eggs of important fishes are kept during their development. In nature very few eggs are allowed to develop because of the attacks of fungi and of animals such as other fishes, crayfishes, and wild fowls. On the other hand, a large percentage of the eggs collected and cared for in fish hatcheries

[1] Fry are fish up to the time the yolk sac is absorbed and feeding begins.

[2] Fingerlings are fish between the length of one inch and the yearling stage.

develop. They are distributed either as well-developed eggs or as young fish, and are planted in the waters from which the adult fishes were taken, and also in waters where the fishes are not native.

In 1909 the Bureau of Fisheries operated 35 hatcheries and 84 subhatcheries, auxiliaries, and egg-collecting stations; these were located in 32 states and territories. The regular hatcheries may be classified as follows with reference to the fishes propagated: marine species, 3; river fishes of the eastern seaboard, 5; fishes of the Pacific coast, 5; fishes of the Great Lakes, 7; fishes of the interior regions, 15. The total output of fish and eggs in 1909 was 3,107,131,911. During the year applications were received for fish for planting in 10,111 different bodies of water. A summary of distributions is given in the table on page 294.

Besides this, 568,150 eggs were shipped to Argentina, France, and Germany.

The Artificial Propagation of the Lake Trout. — The methods employed in artificially propagating fish may be illustrated by an account of the lake trout. Adult lake trout are captured chiefly during the spawning season in September, October, and November in gill nets, pound nets, or by hook and line. Government employees called spawn takers accompany the fishermen on their trips to collect the eggs of the fish captured or else the fishermen themselves are forced to collect the eggs for the government. The ripe females are selected and their eggs squeezed out by the spawn takers, a process known as *stripping*. The eggs are allowed to fall into a milk pan. They are then fertilized by squeezing some of the milt (spermatozoa) from a ripe male into the pan and stirring up the eggs with the tail of the fish. When the pan is half full, the eggs are washed and transferred to a five-gallon pail. Each pail holds about 75,000 eggs.

The eggs thus obtained may be kept at *field stations* for several days or shipped directly to the *hatchery*. In either case they are placed on shallow trays, each holding 10,000 eggs, and eighteen of these trays are placed in a box with moss packed around them.

When the boxes reach the hatchery, the trays are removed and the eggs transferred to other trays that fit into the hatching troughs. Each of these trays holds 6000 eggs, and one hatching trough when filled contains 5,000,000 eggs. Cold water is kept continually flowing over the eggs at the rate of seven gallons per minute. Every three days the trays are carefully examined and all eggs that are dead or are attacked by fungous diseases are picked out.

The eggs begin to hatch in from 75 to 90 days according to the temperature of the water. They are shipped to the waters in which they are to be planted shortly before they hatch, or else they are allowed to hatch and the young fry are planted.

The methods of propagation depend upon the habits of the fish and the weight of the eggs. Fishes that do not care for their eggs or young, like the lake trout and whitefish, can be propagated as described above. Other species, like the black bass, lay a lesser number of eggs, but guard them. Such fish are kept in ponds and protected during the spawning season. Eggs like those of the lake trout are heavy and must be spread out in thin layers on trays, but the comparatively light eggs of such fish as the whitefish are hatched in glass jars, each jar containing five quarts or 200,000 eggs. Water must flow through these trays or jars continually.

Work of the United States Bureau of Fisheries. — The United States Bureau of Fisheries was organized in 1871 as an independent institution, but in 1903 it was included in the new Department of Commerce and Labor. It consists of three principal divisions: (1) Fish Culture, (2) Scientific Inquiry, and (3) Statistics and Methods of the Fisheries.

Some idea of the work done along fish cultural lines may be gained from the preceding paragraphs on the artificial propagation of fishes. The efforts of the bureau have not been limited to fish, however, but the propagation of lobsters, oysters, sponges, fresh-water mussels, and diamond-back terrapins has been studied and in most cases successfully accomplished.

The bureau owns two large seaside laboratories where inquiries of a scientific nature are being made every summer. One of these is at Woods Hole, Mass. (Fig. 176), the other at Beaufort, North Carolina.

Surveys of offshore fishing grounds, the study of deep-sea fishes, and general explorations of the sea are constantly being

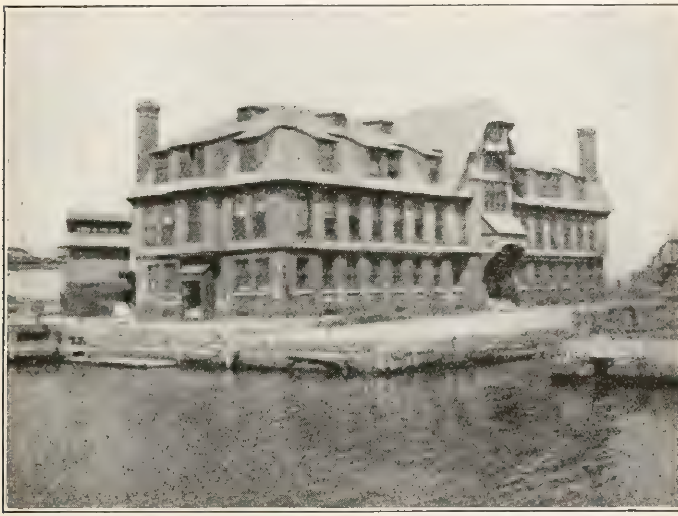

FIG. 176. — The Laboratory Building of the U. S. Bureau of Fisheries at Woods Hole, Mass.

made with the aid of two steamers, the *Albatross* and the *Fish Hawk*.

About 70 large volumes have been published by the bureau. These volumes contain papers on various subjects which may be classified as follows: —

1. Annual report of the commissioner.
2. Fish culture:
   (*a*) Methods.
   (*b*) Distribution of fish and eggs.
   (*c*) Fish diseases and parasites.

3. Aquatic biology:
   (*a*) Economic investigations.
   (*b*) Explorations and surveys, the methods, apparatus, etc.
   (*c*) Descriptions of species and faunal lists.
   (*d*) Morphological, physiological, and pathological studies.
4. Commercial fisheries and related industries.

Papers on any of these subjects are mailed free of charge to any one asking for them so long as there are any copies on hand.

REFERENCES

See end of Chapter XXIX.

CHAPTER XXXII

THE AMPHIBIA

The toads, frogs, salamanders, and a few other animals belong to the class *Amphibia*. The toads and frogs are easily recognized, but the salamanders are often confused with the lizards among the reptiles. Lizards, however, are covered with scales, and salamanders are naked. The eggs of amphibians are usually

Fig. 177. — Photograph of living mud puppy. (From Report N. Y. Zool. Soc.)

laid in the water, like those of the frog, and the young spend their larval life in the water breathing by means of gills. Some amphibians remain in the water throughout life, but most of them forsake the water as soon as they lose their gills and acquire lungs, and they may be found in damp places.

Tailed Amphibians. — The salamanders, mud puppies, and newts are tailed amphibians. The largest of these is the giant salamander of Japan, which reaches a length of over five feet.

The *hellbender* and *mud puppy* (Fig. 177) occur in streams in the eastern United States.

The *crimson-spotted newt* (Fig. 178) is common in the ponds of the northern and eastern portions of the United States. It is about three and one half inches long and has a row of crimson spots on either side. Its food consists principally of insect larvæ, worms, and small mollusks. The eggs are laid in April,

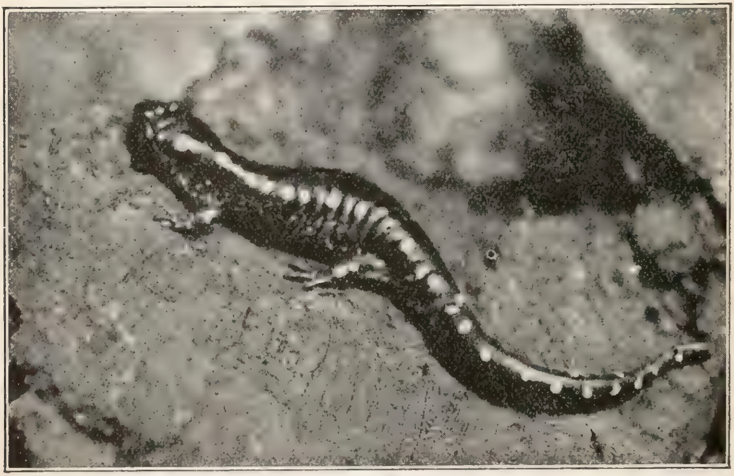

Fig. 178. — Crimson-spotted newt. (Photograph of living animal furnished by American Museum of Natural History.)

May, or June, and a sort of "nest" of aquatic vegetation is constructed for each egg. The young live for a time on land under stones and logs, but return to the water after several years, becoming aquatic adults. In western North America occurs another species of newt.

The *tiger salamander* (Fig. 179) is an inhabitant of fresh water all over this country. It is dark-colored, marked with yellow spots, and reaches a length of from six to nine inches. If forced to breathe air, the tiger salamander loses its gills, but if water is always at hand, the gills persist throughout life as func-

tional respiratory organs. Salamanders in general feed on worms, insects, crustaceans, and other small animals.

Several of the salamanders have legs that are very small or else absent altogether. One of these, known as the " mud eel " (Fig. 180), inhabits the ponds and rivers of the South from Texas to North Carolina. It burrows in the mud of ponds and ditches or swims by undulations of the body. The fore limbs of

FIG. 179. — Tiger salamander. (Photograph of living animal furnished by American Museum of Natural History.)

the mud eel are very small and the hind limbs are entirely lacking.

Tailless Amphibians. — The tailless amphibians, the toads and frogs, are much more numerous than their tailed relatives. They are all very similar in structure, although the different species vary in size and general appearance. In North America there are about fifty-six species. Some of them (toads and tree frogs) live on land, but others (water frogs) spend a large part of their time in the water. The terrestrial species possess only slightly webbed hind feet or no webs at all. They crawl or hop on land, burrow in the earth, or climb trees. Dark, moist hiding places are usually required, and most of them take to water only during the breeding season.

The *leopard frog* (pp. 245–267) is the most common of the water frogs, but it has a number of relatives in this country worth mentioning. Of these the *bullfrogs* are the largest, reaching a length of six or eight inches. They possess a

FIG. 180. — Mud eel. (Photograph of living animal from Report N. Y. Zool. Soc.)

deep, bass voice like that of a bull, and when a number are engaged in a nocturnal serenade, they can be heard for a considerable distance. Bullfrog tadpoles do not become frogs the first year as do those of the leopard frog, but transform during the second or even the third year.

Fig. 181. — Green frog. (Photo. of living animal furnished by American Museum of Natural History.)

The *green frog* lives in eastern North America. It can be distinguished from the bullfrog by the presence of two folds of skin along the sides of the back (Fig. 181).

The *tree frogs* (Fig. 182) are often erroneously called tree toads. They have adhesive disks on their toes and fingers, which enable them to climb trees, and are provided with large vocal sacs which give them a correspondingly loud voice.

Fig. 182. — Tree frog. (Photo. of living animal furnished by American Museum of Natural History.)

The *common tree frog* is about two inches long. It has the power of slowly changing its color so as to produce a perfect harmony between itself and its surroundings. These colors are due to pigments in the skin, usually brown, black, yellow, or red, which are contained in cells called chromatophores (Fig. 184). The power of changing its colors is possessed by most Amphibia, but especially by the tree frogs. The black chromatophores are

branching cells which may spread out or contract, as shown in Figures 183–185. When expanded, the pigment covers a larger area and consequently gives the skin a darker color. The yellow pigment is contained in spherical golden cells. The green color results from the reflection of light from granules in the skin through the golden cells. Most of the color changes are due to changes in the concentration of the black and yellow pigments.

FIG. 183. — A pigment cell of a frog extended. (After Verworn.)

Regeneration.—The power of regenerating lost parts is remarkably well developed in many Amphibia. For example, the hand of a two-year-old axolotl was cut off, and in twelve weeks a complete hand was regenerated in its place. The newt has been observed to regenerate both limbs and tail. The frogs and toads are apparently unable to regenerate lost parts to any considerable extent, except in the early stages. As a general rule, the younger tadpoles regenerate limbs or tail more readily than older specimens. Amphibians have a distinct advantage in the possession of the power of regeneration; for although an encounter with an enemy may result in

FIG. 185. — A pigment cell of a frog in a further state of contraction. (After Verworn.)

FIG. 184. — A pigment cell of a frog in state of contraction.

the loss or the mutilation of limb or tail, new parts rapidly grow out, and they are not permanently inconvenienced by the loss.

Hibernation. — Many Amphibia bury themselves in the mud at the bottom of ponds in the autumn, and remain there in a dormant condition until the following spring. During this period of hibernation the vital processes are reduced. No air is taken into the lungs, since all necessary respiration occurs through the skin; and no food is eaten, but the physiological activities are carried on by means of nutriment stored in the body. The temperature of all cold-blooded vertebrates — lampreys, sharks, rays, fish, amphibians, and reptiles — varies with the surrounding medium. Frogs cannot, however, be entirely frozen, as is often stated, since death ensues if the heart is frozen. In warm countries many Amphibia seek a moist place of concealment in which to pass the hotter part of the year. They are said to æstivate.

Poisonous Amphibia. — The poison glands of the leopard frog have already been mentioned (p. 253). The toads and certain salamanders and newts are also provided with poison glands. As a means of defense the poison is very effective, since an animal that has once felt the effects of an encounter with a poisonous amphibian will not soon repeat the experiment. No amphibians, however, are harmful to man.

The Common Toad. — One of the commonest and most valuable of all amphibians is the toad (Fig. 186). This much-detested animal is not responsible for all the evil things laid up against it. It does not cause warts to appear on the hands that touch it; it is not poisonous; and it will not, if killed, make the cows give bloody milk, as is often believed in the country. On the other hand, toads are not only perfectly harmless to man, but are among the most beneficial of all animals because they destroy harmful insects and slugs. They live in our gardens if they can find a damp and hidden retreat, and they sally forth toward evening in search of insects and other small animals, most of which are injurious to vegetation. In twenty-four hours the toad consumes "a quantity of insect food equal to about

four times its stomach capacity." This capacity may be judged from the fact that sixty-five gypsy-moth caterpillars have been found in one stomach, fifty-five army worms in another, and seventy-seven thousand-legged worms in a third.

One method, therefore, of ridding a garden or an estate of injurious insects is to establish a number of toads in it. In

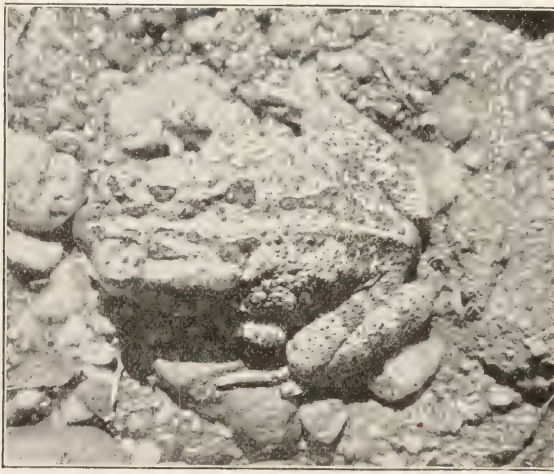

FIG. 186. — American toad. (Photo. of living animal from Davenport.)

England and France toads are purchased for this purpose. This method will certainly be successful, but it is far better to spread the knowledge of the toad's real status and thus prevent the destruction of these beneficial creatures.

Toads become strongly attached to one locality and will return to it year after year at the end of the breeding season. In the spring they migrate to the nearest body of water in which to lay their eggs. A toad lays about ten thousand eggs, almost all of which hatch. The tadpoles are destroyed by birds, fish, and large water insects, so that only a few ever have a chance to change into toads. Those that do succeed in reaching the adult stage should certainly be protected.

The results of a campaign of education are well shown by an experiment carried on by Professor Hodge at Worcester, Mass. Professor Hodge reports as follows: —

"While walking once around a small pond I counted 200 toads dead or mangled and struggling in the water, and learned next day that two boys had killed 300 more, carrying them off in an old milk can to empty on a man's doorstep. This 500 does not represent probably one tenth of the number killed by the children that spring (1897) around this one pond. A 'civilization' in which such abuses of nature are possible ought to be eaten alive by insects, and something must be fundamentally wrong with a system of public education that does not render such a thing impossible. My first impulse was to get a law passed and appeal to the police, but the wiser counsel of a friend prevailed, and I was induced to try education of the children instead. Accordingly, a prize of $10 was offered to the Worcester school child who would make the best practical study of the 'Value of the Common Toad.' This was offered March 31, 1898, and there was no evidence that a single toad was harmed at the pond the following April and May. I would have been well satisfied had such a result been attained in five years. The fact that it came within thirty days reveals the possibility of nature study when united to human interest."

The Economic Importance of Amphibia. — Only certain frogs, toads, and salamanders are abundant enough to be of any particular economic importance. These, however, are probably without exception mostly beneficial because of the injurious insects and other animals they destroy. The common toad is the most beneficial of all, but others are also valuable.

Besides their importance as destroyers of insect pests certain amphibians, especially bullfrogs, are eagerly sought as an article of food. In certain states attempts have been made to prevent the wholesale destruction of frogs, and some efforts have been made to carry on frog "farming," but these have not been very successful in close quarters because the frogs eat each other, and

their food of small animals can be obtained for them only with difficulty.

Finally the fact should be mentioned that many of the things we know about the physiology of animals have been learned from experiment on frogs, in fact the frog seems to have been "especially designed as a subject for biological research."

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CHAPTER XXXIII

THE REPTILIA

THE word "reptile" means to most people a slimy, poisonous creature, but as a matter of fact reptiles are not slimy and very few of them are poisonous. There are four large groups of reptiles, and the members of any one group differ strikingly from those of the others. They are the turtles, snakes, lizards, and

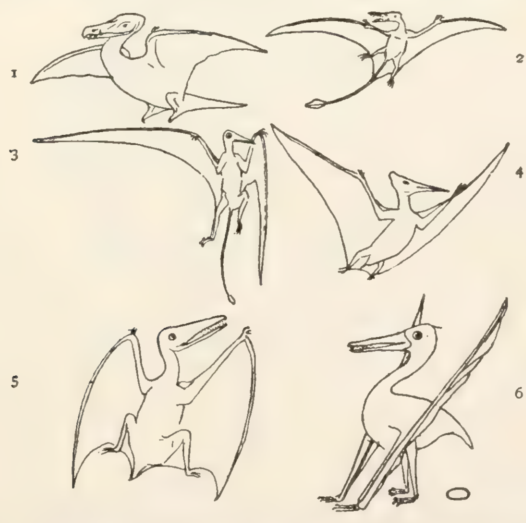

FIG. 187. — Diagrams of the extinct reptiles, called pterodactyls, in various positions. (From Seeley.)

crocodiles. Reptiles live in all sorts of habitats, in the sea and in fresh water, in the ground, on the ground, and in trees. In prehistoric times there were reptiles that could fly (Fig. 187), but none of them exist now.

Turtles

Turtles are favorable reptiles for laboratory study because of their size, because they are easily obtained, and because they are not so generally abhorred as are most other species. The

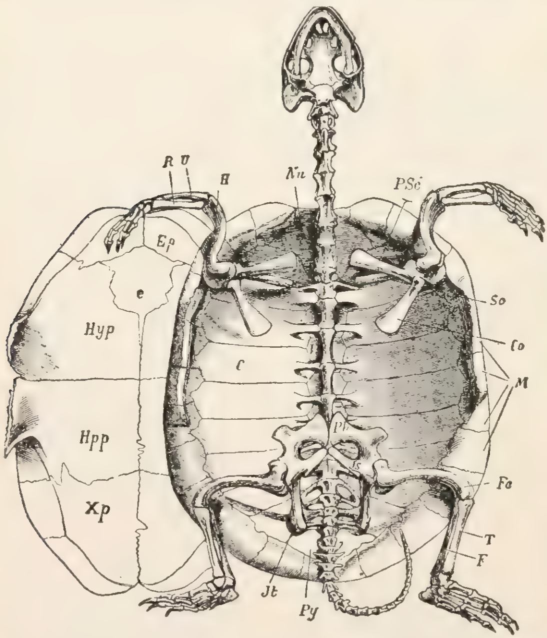

FIG. 188. — Skeleton of a turtle, ventral aspect; plastron removed to one side.

c, costal plates; **co**, coracoid; **e**, entoplastron; **ep**, epiplastron; **f**, fibula; **fe**, femur; **h**, humerus; **hpp**, hypoplastron; **hyp**, hyoplastron; **jl**, ilium; **js**, ischium; **m**, marginals; **nu**, nuchal; **pb**, pubis; **psc**, precoracoid; **py**, suprapygal; **r**, radius; **sc**, scapula; **t**, tibia; **u**, ulna; **xp**, xiphiplastron. (From Zittel.)

most striking thing about a turtle is its protective shell (Fig. 188). In most species this covers almost the entire body, and the legs, head, and tail can be drawn into it. Such an animal does not need to run away at the approach of an enemy, and the turtle

is extremely slow in its movements. The shell of the turtle consists of bone. It does not really cover the body since it lies beneath a coat of horny shields.

Method of Feeding. — Of great service to an animal of the turtle's habits of sluggish locomotion is the long, flexible neck which enables it while lying quietly in one place to reach out in any direction for the insects and other small animals upon which it feeds. Some turtles live entirely upon vegetation, which of course can be obtained without rapid locomotion. The large mouth is toothless, but the margins of the jaws are edged with horny plates adapted to cutting. The snapping turtle can bite off a finger and large specimens can even amputate a hand.

Internal Organs. — The turtle's digestive system differs very little from that of the frog. Its heart also consists of the same parts, two auricles and one ventricle, but the ventricle is divided into two chambers by a perforated partition. The young of the turtle as well as the adults breathe with lungs, no gills being present.

Nervous System. — Slight advances in the development of the nervous system over that of the frog are evident in the turtle. The cerebral hemispheres of the brain are larger, and a distinction can be made between an outer gray layer and a central white portion. The cerebellum is also larger, indicating an increase in the power of correlating movements.

Sense Organs. — The eyes are small, with an iris which is often colored. The sense of hearing is fairly well developed, and turtles are easily frightened by noises. The sense of smell enables the turtle to distinguish between various kinds of food both in and out of the water. The skin over many parts of the body is very sensitive to touch.

Egg Laying. — Turtles are bisexual. Their eggs are whitish, spherical, or oval in shape, and covered with a more or less hardened shell. They are laid in the earth or sand a few inches from the surface, where they are left to hatch.

FIG. 189. — Snapping turtle. (Photo. of living animal. Copyright by Doubleday, Page and Co.)

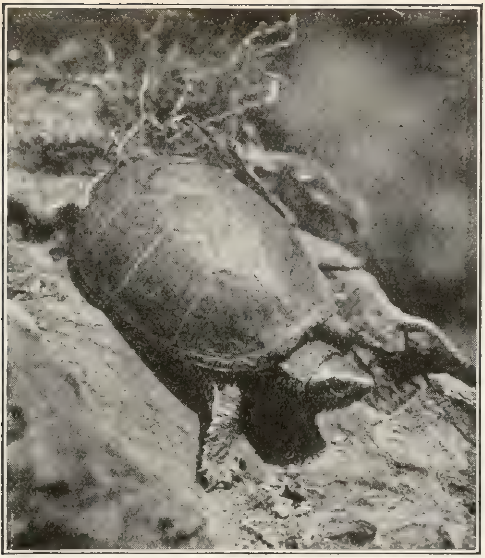

FIG. 190. — Musk turtle. (Photo. of living animal furnished by American Museum of Natural History.)

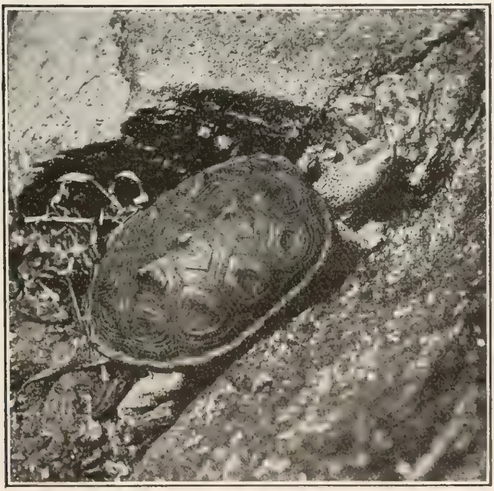

FIG. 191. — Diamond-back terrapin. (Photo. of living animal furnished by American Museum of Natural History.)

Habitat. — Turtles are usually present in all fresh-water streams and ponds with muddy bottoms. In some parts of the country certain species live on land, and some parts of the sea are inhabited by others. The names turtle, tortoise, and terrapin are often confused, illustrating the value of scientific terms (see p. 106).

Fig. 192. — Soft-shelled turtle. (Photo. of living animal. Copyright by Doubleday, Page and Co.)

Fresh-water Turtles. — The common turtles living in muddy-bottomed streams and in ponds are the snapping turtle, mud turtle, painted terrapin, pond turtle, and soft-shelled turtle.

The common *snapping turtle* (Fig. 189) is a voracious, carnivorous animal feeding on fish, frogs, water fowl, etc., and does not hesitate to attack man with its formidable beak, often

inflicting severe wounds. It must be fierce in order to protect itself, since its shell is very small and offers little protection for the body.

The common *musk turtle* (Fig. 190) has a shell three or four inches long, a large head, and broadly webbed feet. Like the snapping turtle it is voracious and carnivorous. The disagreeable odor it emits when captured has given it its name.

The *painted terrapin* loves to sun itself upon a log or protruding rock, from which it slides off into the water when disturbed. Its shell, which is beautifully colored, is sometimes cleaned, varnished, and used as an ornament.

The *diamond-back terrapin* (Fig. 191) is famous as an article of food. It lives in the salt marshes of the Atlantic coast. Persistent persecution by market hunters has caused a great decrease in the number of these animals and a corresponding increase in their value. The price has risen from twenty-five cents for a large specimen to seventy dollars per dozen for small ones.

Fig. 193. — Box tortoise. (Photo. of living animal furnished by American Museum of Natural History.)

The *soft-shelled turtles* (Fig. 192) are thoroughly aquatic and have large, strongly webbed feet. The body is flat, the neck is long and very flexible, the nose terminates in a small proboscis,

and the shell is leathery without shields and with only a few scattered bones. These turtles are voracious and carnivorous, and when attacked, they are very vicious. The shells as well as other parts of the animals are used as food and are regularly sold in the markets.

Terrestrial Turtles.— The turtles that are terrestrial in habit include the box turtle, gopher tortoise, and giant tortoise.

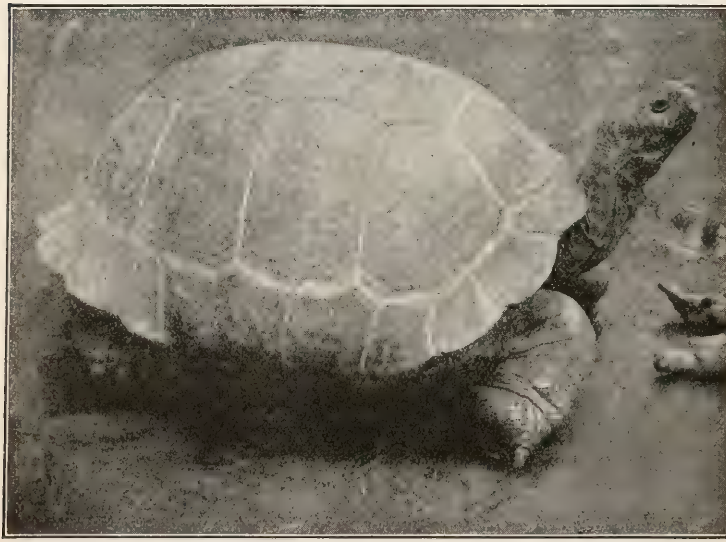

FIG. 194. — Giant tortoise. (Photo. of living animal. By permission. Copyright 1910 by Sturgis and Walton Co.)

The common *box turtle* (Fig. 193), which occurs in the Northeastern States, lives in dry woods and feeds on berries, tender shoots, earthworms, and insects. The lower part of the shell is hinged transversely near the center so that it can be closed completely when the animal is in danger.

The *giant tortoises* (Fig. 194) are interesting not only because of their great size, but also because they are living representatives of the fauna of past ages. Some of those captured on the Galap-

agos Islands weigh over three hundred pounds and are probably over four hundred years old. These giant tortoises live on cacti, leaves, berries, and coarse grass. They have been persecuted for food and for scientific purposes so persistently that extermination in a wild state seems certain within a few years.

Sea Turtles. — The sea turtles are the giants of the turtle class. The *green turtle* (Fig. 195), so called because of the green

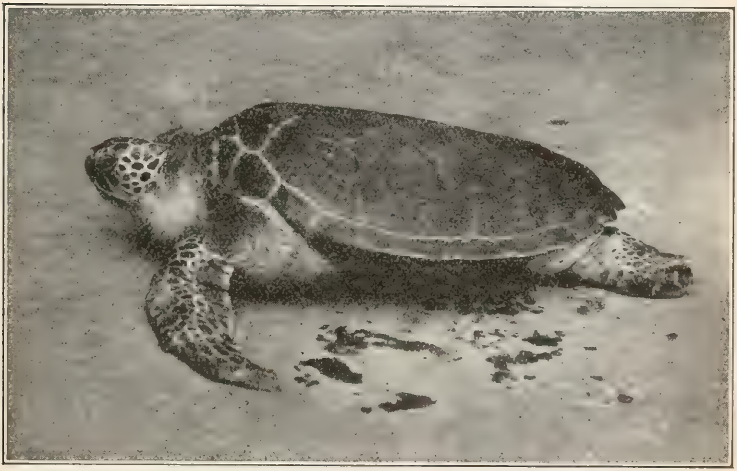

FIG. 195. — Green Turtle. (Photo. of living animal furnished by American Museum of Natural History.)

color of its fat, sometimes has a shell four feet in length, and weighs 500 pounds. It is famous as an article of food, and is common in the markets of the large cities of the eastern United States. It feeds largely on aquatic vegetation, and probably eats fish and other animals also.

The *hawk's-bill* or *tortoise-shell turtle* (Fig. 196) has the shields of its carapace arranged like the shingles on a roof. These shields of which a large specimen yields about eight pounds, are the "tortoise shell" of commerce. The shields are detached either after the turtles have been killed and immersed in boiling

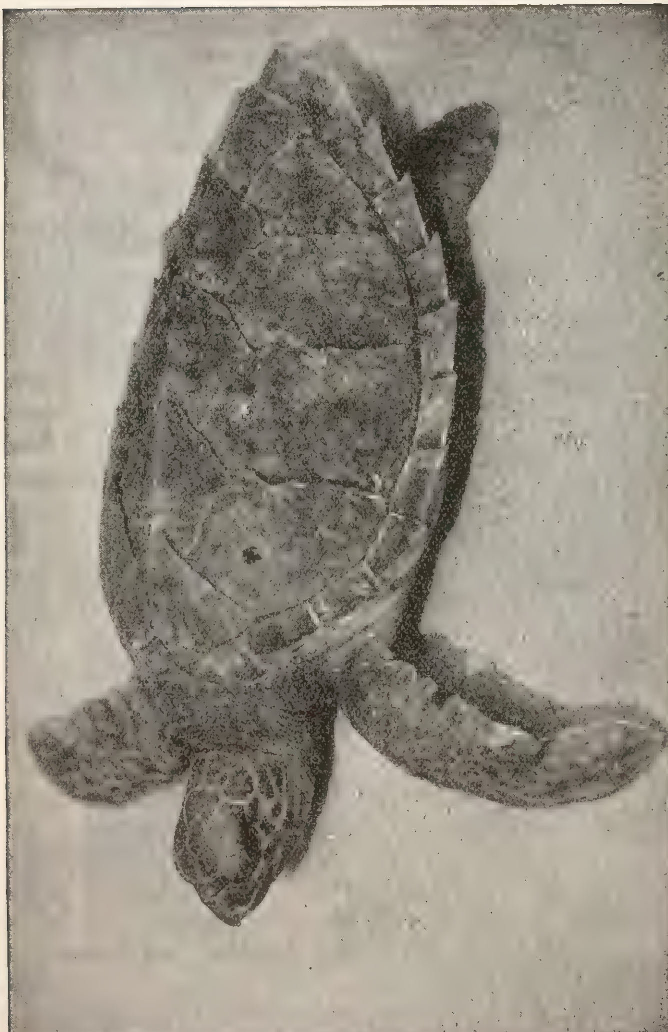

FIG. 196. — Hawk's-bill turtle. (Photo. of living animal. Copyright by Doubleday, Page and Co.)

water or after the living animals have been suspended over a fire. In the latter case the animals are liberated and allowed to regenerate a new covering of shields. The regenerated shields, however, are not of commercial value. Hawk's-bill turtles are smaller than green turtles, reaching a weight of about thirty pounds and a shell length of thirty inches. They are carnivorous, feeding largely on fish and mollusks.

The *leathery turtle* is the largest of all living turtles, sometimes attaining a weight of a thousand pounds. It has a leathery covering over the shell instead of horny shields. It inhabits tropical and semitropical seas and goes to land only to deposit its eggs. The limbs are modified as flippers for swimming. The flesh is not used for food.

Lizards

The lizards resemble salamanders in their general outlines, but as already noted (p. 299) they are covered with an exoskeleton of scales. Among the common species living in this country are the chameleons, iguanas, horned "toads," gila monsters, and skinks.

The *chameleon* lives in southeastern United States and in Cuba. It is able to change its color very rapidly so as to match its surroundings, thus concealing itself and gaining protection.

From southwestern United States southward huge *iguanas* (Fig. 197) are commonly seen lying on stone fences or on the limbs of a tree sunning themselves. They reach a length of six feet, feed on insects and other small animals, and are considered very good to eat by the natives of tropical America.

The *horned "toads"* (Fig. 198) of the western United States are really lizards. Their bodies are provided with a very heavy covering of scales and spines, which, besides protecting them from enemies, prevents the evaporation of water, thus enabling them to live in hot, dry, desert regions. Specimens can be kept in the laboratory if placed in a warm, dry place. They feed on insects in their natural habitat and will thrive on meal worms in captivity.

FIG. 197. — Iguana. (Photo. furnished by American Museum of Natural History.)

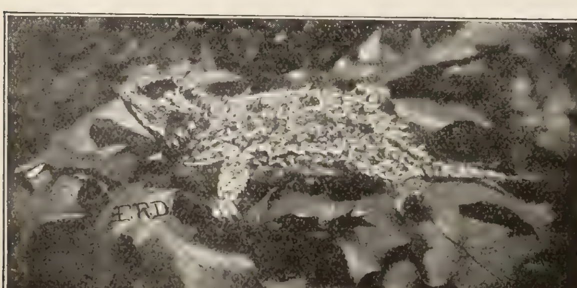

FIG. 198. — Horned "toad." (Photo. of living animal. From Davenport.)

The common lizards of the eastern and central United States are called *skinks* (Fig. 199). Young skinks have a blue tail and black body, with five long yellow stripes on the sides. The adult females retain these colors, but the males acquire a bright red head and a dull, olive-brown body.

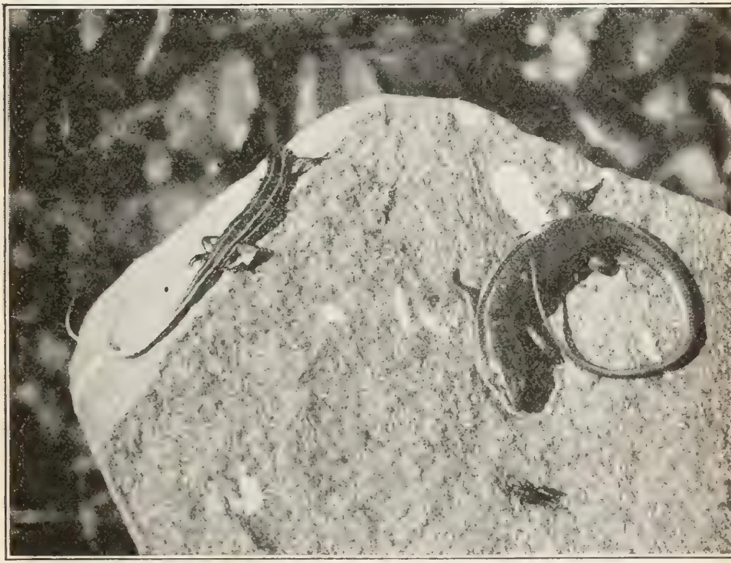

FIG. 199. — Skinks. (Photo. of living animals furnished by American Museum of Natural History.)

The only poisonous lizard in this country is the *gila monster* of Arizona and New Mexico (Fig. 200). This reptile is about one foot in length and heavy bodied. Its bright red and black colors make it quite conspicuous (warning coloration, see p. 30), but its poisonous nature is an excellent protection from enemies. Gila monsters are, as a rule, not harmful to man. Their grooved poison teeth (fangs) are in the lower jaw so the animal must turn over on its back before the poison will flow down into a wound.

The *glass "snake"* (Fig. 201) is a lizard without limbs and with a very brittle tail. It may easily be confused with the true snakes, but is distinguished from them by the presence of ear openings and movable eyelids.

Fig. 200. — Gila monster. (Photo. of living animal. From Metcalf.)

Snakes

The snakes are degenerate reptiles entirely without legs except in a few examples like the python, on which spearlike remnants occur. The exoskeleton of *scales* is shed several times a year and a fresh, clean covering acquired. Snakes require a rough surface for locomotion on land. They press the scales on the ventral surface against the ground, and by sidewise undulations draw the body forward. Snakes that normally live in the water are able to swim rapidly by similar undulations, and most of the terrestrial species can also swim.

The *eyelids* of the snake are not movable as are the lizard's,

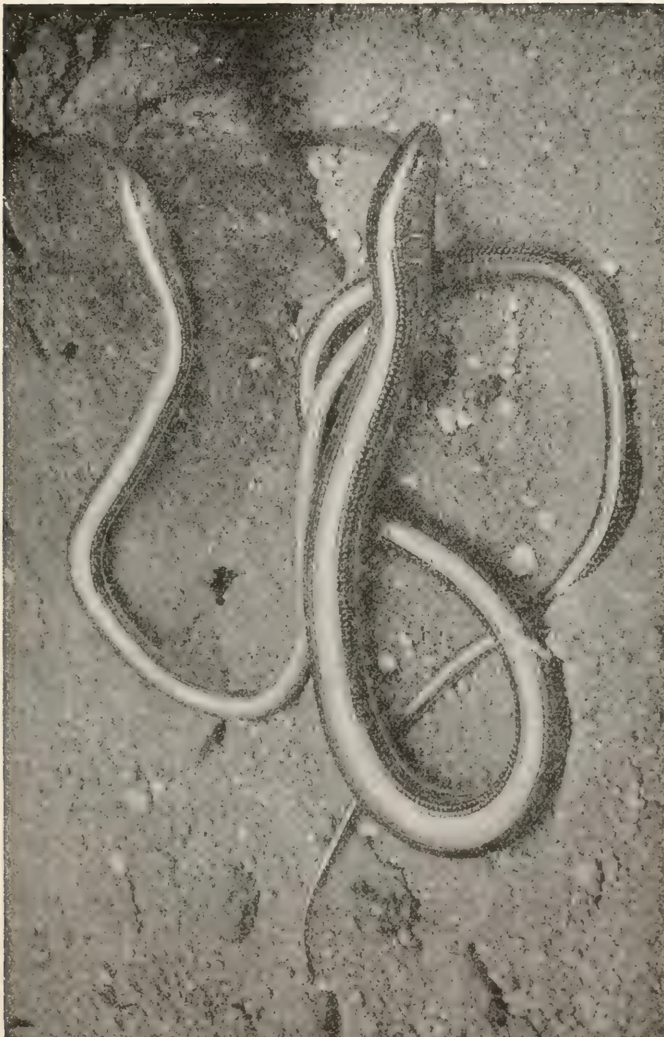

Fig. 201. — Glass "snake." (Photo. of living animals. Copyright by Doubleday, Page and Co.)

but they are fused over the eyeball. In the center is a transparent part through which the reptile receives light waves. Ear openings are lacking and the sense of hearing is consequently very feeble. The long forked tongue, however, which is often erroneously considered injurious, is very sensitive to vibrations and probably serves as an auditory organ.

As in the amphibians and lizards, the teeth are sharp, conical structures fitted for holding struggling animals. They are curved inward and help the snake force the food down the throat. A snake can swallow objects much thicker than its own body; this is due to the elasticity of the body and to the fact that the jaws are loosely fastened together.

Most of the snakes lay eggs, but in a few cases, for instance the common garter snake, the eggs hatch within the body of the mother and the young are then born. There is no reason for believing the popular story that snakes swallow their young to protect them and then disgorge them again when the danger is past.

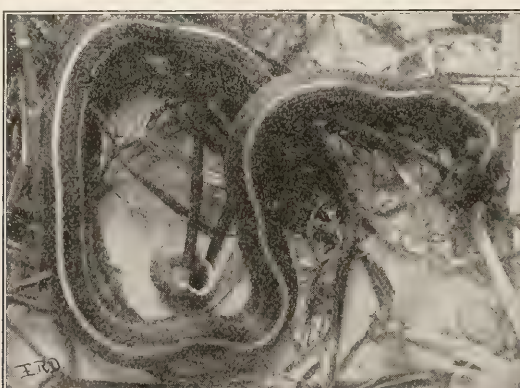

FIG. 202. — Garter snake. (Photo. of living animal. From Davenport.)

Harmless Snakes. — Only a few of the snakes inhabiting North America are poisonous; most of them are either of no special importance or else beneficial. The commonest snakes

are the *grass* or *garter snakes* (Fig. 202) which occur all over this country. The body is olive color with three long yellow stripes; this renders it rather inconspicuous and enables it to creep upon the frogs, toads, fishes, and earthworms which serve it as food, without being seen (aggressive coloration, see p. 30). The eggs of the garter snake hatch within the body and the young emerge in August.

Contrary to general belief, most of the *water snakes* are as harmless as the garter snakes. Like the frogs, they live in swampy places, and escape into the water when approached closely. The common water snake is frequently called "water moccasin," but these two species are quite different.

FIG. 203. — Black snake or "blue" racer. (Photo. by Hegner.)

Among the other harmless snakes that one is apt to encounter are the *black snake* or "*blue*" *racer* (Fig. 203), which lives in dry, open situations and feeds on small animals such as mice, frogs, and young birds; the *milk snake*, which is wrongly accused of stealing milk from cows; the *hog-nosed snake*, commonly known as the "puff adder," "spreading viper," or "blow snake," be-

cause of its habit of trying to frighten an enemy by expanding its neck like a cobra and hissing; and the *king snake*, which feeds on other snakes, hence its name.

Constrictors. — There are no very large snakes in North America, but in tropical South America the *boa constrictor* (Fig. 204) reaches a length of eleven feet, and the water boa or *anaconda* a length of over seventeen feet. The largest of all snakes

FIG. 204. — Boa constrictor. (By permission. Copyright by Sturgis and Walton Co.)

is the *regal python* of Burma (Fig. 205), which may grow to be thirty feet long. All of these large snakes are constrictors; that is, they capture birds and mammals and squeeze them to death in their coils. Very few of them are dangerous to man.

Poisonous Snakes. — The only poisonous snakes in this country are the rattlesnakes, copperhead, water moccasin, harlequin snake, Sonoran coral snake, and a few small species in-

FIG. 205. — Python. (By permission. Copyright by Sturgis and Walton Co.)

FIG. 206. — Rattlesnake. (Photo. by Hegner.)

habiting the southern part of the United States that are practically harmless.

The *rattlesnakes* (Fig. 206) occur almost all over the United States, but are particularly abundant in the deserts of the southwest. The largest species, the *diamond-back rattlesnake*, occurs in the Southeastern States, and reaches a length of over eight feet. The *banded rattlesnake* is a resident of the Eastern States; the *massasauga* inhabits the Central States; and the *horned rattlesnake* is common in the deserts of the Southwest.

The *rattles* of these snakes are strings of bell-shaped pieces of exoskeleton, each piece representing what was once the end of the tail. The skin is shed several times a year, but the bell-shaped " button " at the end of the body does not come off, being added to the rattles already present. Rattles are often lost so that the age of the snake cannot be determined by counting them. The rattles are used to warn other animals of the presence of the snake; when vibrated, they produce a buzzing sound.

Fig. 207. — Poison apparatus of rattlesnake. (Photo. furnished by American Museum of Natural History.)

The *poison apparatus* of the rattlesnake (Fig. 207) consists of a pair of poison glands lying above the roof of the mouth, which are connected by ducts with a pair of long, hollow teeth, the fangs, situated near the outer end of the upper jaw. When the snake strikes, the jaws are opened very

Fig. 208. — Water moccasin. (Photo. of living animal. Copyright by Doubleday, Page and Co.)

wide and the fangs are thrust into the victim. Then certain muscles force the poison from the poison glands through the hollow fangs into the wound. Extracting the fangs from one of these snakes does not render it harmless for long, since there are a number of pairs of small teeth held in reserve, which soon grow into functional fangs.

The common *treatment for snake bite* is the administering of alcohol and sucking the wound. Neither of these is of much

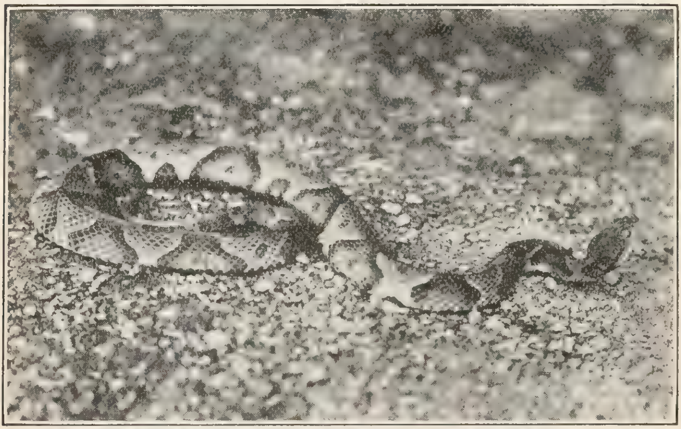

Fig. 209. — Copperhead snake. (Photo. of living animal furnished by American Museum of Natural History.)

benefit. The first thing that should be done is to stop the flow of blood toward the heart by applying a ligature above the wound. Then incisions should be made through the wound to get rid of as much poison as possible, and a solution of potassium permanganate should be injected about the wound to destroy the venom. An antivenin has been produced which when injected into the body destroys the venom in the blood, but unfortunately the poison from every kind of snake requires a different sort of antivenin.

The *water moccasin* (Fig. 208) is a very poisonous snake. It lives in the swampy lands of the Southeast. and reaches an

average length of four feet. This species, the copperhead, and rattlesnakes are all known as pit vipers because of the presence of a deep pit between each eye and the nostril. These pits are so small, however, that a snake must be examined rather closely in order to determine whether or not they are present. Hence one must rely on other characteristics to identify them at a distance.

The *copperhead* (Fig. 209) is another poisonous snake of the southeastern United States. It occurs on the plantations and in or near forests, and is about two and one half feet long.

The *harlequin snake* and *coral snake* are so small as to be of very little importance, but their relative, the *cobra-de-capello* of the Orient, is a very dangerous reptile. In a single year (1908) about twenty-thousand natives were killed by cobras in India.

Crocodiles and Alligators

Crocodiles and their near relatives look very much like large lizards (Fig. 210). They are adapted for life in the water, with the toes of the hind feet more or less webbed, and the tail compressed laterally, making it an effective swimming organ. The exoskeleton of the crocodile consists of a thick, leathery skin, covered with horny scales and horny plates, and is, therefore, a good protection from injury. Several of the internal organs of these reptiles are worth mentioning here. The ventricle of the heart is completely divided into two parts by a partition (see p. 311), and the body cavity is divided into two chambers as in mammals, the anterior chamber containing the lungs.

The *American crocodile* occurs along the streams from Florida southward into South America. Its head is broad at the base and narrow at the snout, whereas that of the alligator is wider at the snout. The crocodile reaches a length of fourteen feet. When in the water it floats at the surface with just its eyes and the nostrils at the end of the snout protruding. It can thus both see and breathe without itself being seen. The crocodile of Africa is a very dangerous man eater and kills hundreds of natives every year.

There are only two species of *alligators* in the world; one lives along the streams of southeastern United States, the other is restricted to China. The alligator has a broad snout, but otherwise resembles the crocodile in general appearance. Its habits also are similar. The twenty to forty eggs are laid in a mound of muck and left there to hatch.

The crocodiles of India are known as gavials. Their snouts are long and slender, and their bodies attain a length of more

FIG. 210. — Alligators. (Photo. by Hegner.)

than twenty feet. Usually they are satisfied with fish as food, but they sometimes attack man.

The Economic Importance of Reptiles. — The food of reptiles consists of both animals and plants. The animals eaten belong to practically all classes. Many of the snakes live almost entirely upon birds and mammals. Frogs, fish, and other reptiles are favorite articles of food. Most of the smaller species of reptiles feed upon worms and insects. In general it may be stated that reptiles do very little damage in destroying animals and plants for food, but they are often of considerable benefit, since they kill large numbers of obnoxious insects and other forms.

The turtles and tortoises rank first as food for man. Es-

pecially worthy of mention are the green turtle, the diamond-back terrapin, and the soft-shelled turtle. It seems possible that turtle farms might prove commercially successful in some parts of this country if established on land useless for other purposes. Certain lizards, such as the iguana of tropical America, are a valuable addition to the food supply in their localities.

The skins of the crocodilians are used rather extensively for the manufacture of articles that need to combine beauty of surface with durability. The alligators in this country have decreased so rapidly because of the value of their hides that they will be of no great economic importance unless they are consistently protected or grown on farms. Of less value are the skins of certain snakes. Tortoise shell, especially that procured from the horny covering of the carapace of the hawk's-bill turtle, is widely used for the manufacture of combs and ornaments of various kinds.

As previously stated, the poisonous snakes of the United States are of very little danger to man. In tropical countries, especially India, venomous snakes cause a larger death rate than that of any other group of animals. The gila monster, which is one of the few poisonous lizards, and the only one inhabiting the United States, very seldom attacks man, and probably never inflicts a fatal wound.

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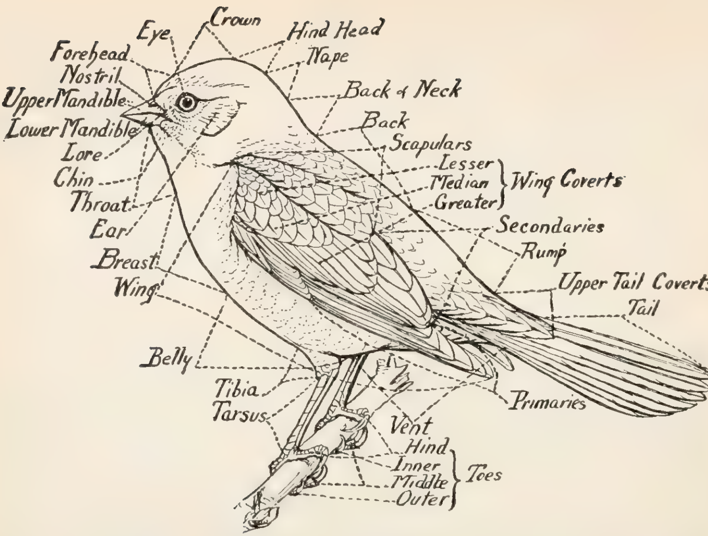

FIG. 211. — Diagram showing names applied to the parts of a bird's body (From Wright.)

FIG. 212. — Pigeons in flight. (Photo. by Hegner.)

CHAPTER XXXIV

THE STRUCTURE AND ACTIVITIES OF BIRDS

BIRDS are to the majority of people the most interesting of all vertebrates. They are easily distinguished from any other animals by the presence of feathers. Besides this, most birds possess wings and are able to fly. Their excellent locomotor powers have enabled birds to become distributed all over the world and to establish themselves in every habitable region.

The Body Built for Flight. — The body of a bird is in general built for flight (Fig. 211). Its shape is such as to offer the least resistance to movement through the air, and its bones are closely united, giving the rigidity required by a body supported only by air (Fig. 212). In the first place, although the vertebræ in the neck move freely upon one another, those of the back are closely united, forming a firm axis (Fig. 213). The thorax is strongly supported by ribs which are entirely of bone and are held together by projections called uncinate processes. The long wing bone, although able to move freely, is more firmly connected with the shoulder girdle than is the bone of the fore limb in other vertebrates. Finally, the breastbone or sternum bears a projection or keel to which the enormous wing muscles are attached, and many of the bones are hollow and therefore decrease the specific gravity of the body. These features are all correlated with the flying habits of the birds.

The Wings as Organs of Flight. — The principal organs of flight are, of course, the wings. When devoid of their feathers, the wings of a bird seem quite ineffective, but the bones within them are very strong and closely knit together. These bones are similar to those in the fore limbs of other vertebrates except the

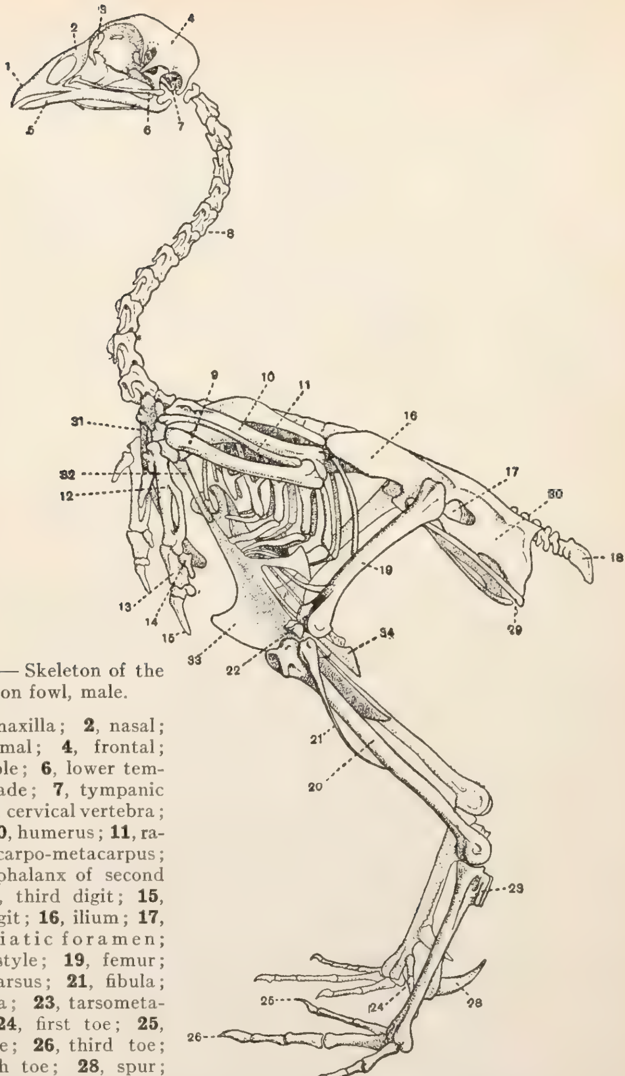

FIG. 213. — Skeleton of the common fowl, male.

1, premaxilla; **2**, nasal; **3**, lachrymal; **4**, frontal; **5**, mandible; **6**, lower temporal arcade; **7**, tympanic cavity; **8**, cervical vertebra; **9**, ulna; **10**, humerus; **11**, radius; **12**, carpo-metacarpus; **13**, first phalanx of second digit; **14**, third digit; **15**, second digit; **16**, ilium; **17**, ilioischiatic foramen; **18**, pygostyle; **19**, femur; **20**, tibiotarsus; **21**, fibula; **22**, patella; **23**, tarsometatarsus; **24**, first toe; **25**, second toe; **26**, third toe; **27**, fourth toe; **28**, spur; **29**, pubis; **30**, ischium; **31**, clavicle; **32**, coracoid; **33**, keel of sternum; **34**, xiphoid process. (From Shipley and MacBride.)

cyclostomes and fishes, but they are modified somewhat by the omission of several of the digits and the union of certain of the

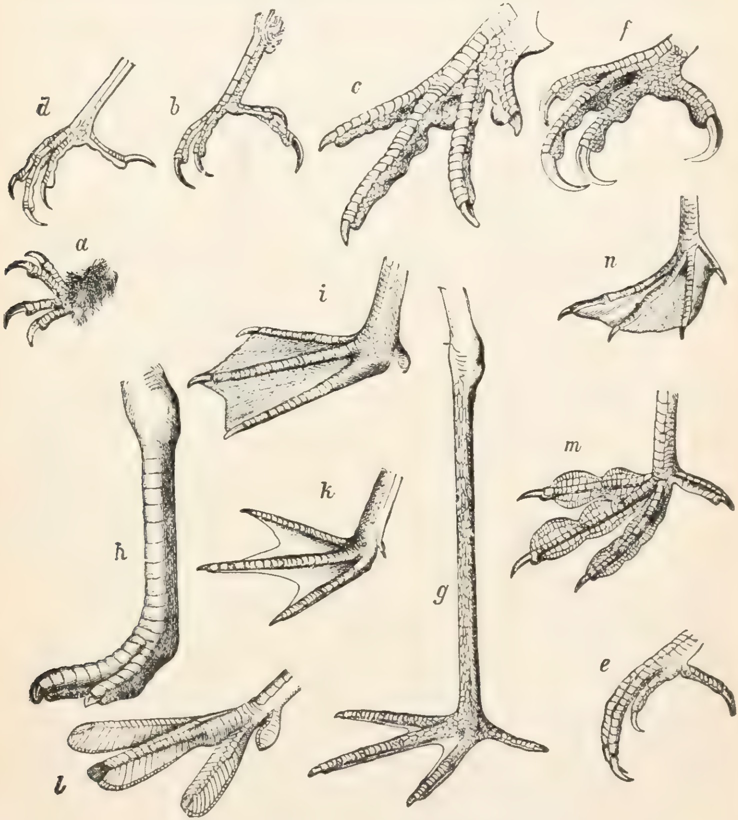

FIG. 214. — The most important forms of birds' feet.

a, clinging foot of a swift; **b**, climbing foot of woodpecker; **c**, scratching foot of pheasant; **d**, perching foot of ouzel; **e**, foot of kingfisher; **f**, seizing foot of falcon; **g**, wading foot of stork; **h**, running foot of ostrich; **i**, swimming foot of duck; **k**, wading foot of avocet; **l**, diving foot of grebe; **m**, wading foot of coot; **n**, swimming foot of tropic-bird. (From Sedgwick.)

bones that remain. To this axis of bones and muscles and tendons the long wing feathers are attached.

These feathers convert the narrow wings into broad surfaces that enable the bird to make powerful strokes against the resistance of the air. The body of the bird is much heavier than the

FIG. 215. — The most important forms of birds' beaks.

a, flamingo; **b**, spoonbill; **c**, yellow bunting; **d**, thrush; **e**, falcon; **f**, duck; **g**, pelican; **h**, avocet; **i**, black skimmer; **k**, pigeon; **l**, shoebill; **m**, stork; **n**, arocari; **o**, stork; **p**, bird of paradise; **q**, swift. (From Sedgwick.)

atmosphere and, unlike that of a land animal in walking, it must be sustained as well as propelled when flying. Downward strokes of the wings prevent the bird from falling just as a

swimmer keeps at the surface by the movements of his arms. These same strokes of the bird are made at such an angle that the wings form an inclined plane, thereby propelling the body forward (see insect flight, p. 10). When brought forward, the wings are bent at the wrist joint, with the narrow edge in front, so that very little resistance is encountered.

Steering the Body during Flight. — The wings also in part steer the bird through the air, since a more powerful stroke on one side swerves the body toward the other side, just as does a stronger pull on one oar of a boat. Steering is, however, largely done with the tail, which serves as a rudder, directing the body upward or downward and from side to side according to the position in which it is held.

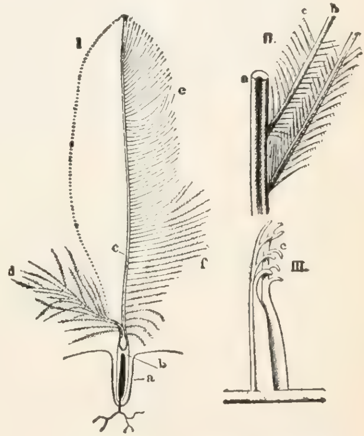

FIG. 216. — The structure of feathers.

I. Contour feather. **a**, quill; **c**, vane; **e**, shaft.

II. Part of shaft (**a**) with two barbs (**b**).

III. Two barbules bearing hooklets (**c**). (From Coleman.)

How the Feet are Used. — While on the ground birds walk, run, or hop, and when in trees, they cling to the twigs with their claws. Their hind limbs must therefore be adapted for these various purposes, as well as for obtaining food, for building nests, and for fighting with other animals.

FEET ARE ADAPTED TO VARIOUS PURPOSES (Fig. 214). — In birds that ordinarily perch on limbs the feet are strong and fitted for grasping. Swimming birds have their toes entirely or partially connected by webs. Wading birds have long legs and long, slender toes which prevent them from sinking into the mud. The toes of the birds of prey are very strong and bear sharp,

curved claws for capturing their prey. Birds that spend most of their time in flight, like the swift, possess weak feet. Usually

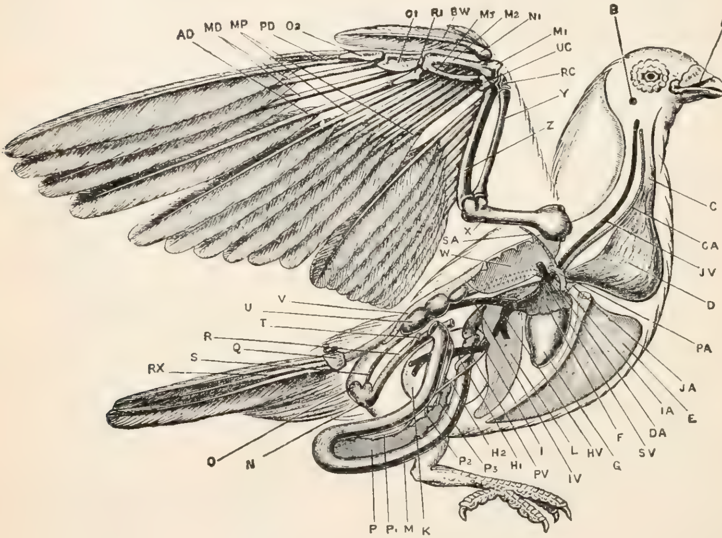

FIG. 217. — Anatomy of the pigeon.

A, nostril; **AD**, ad-digital primary feather; **B**, external auditory meatus; **BW**, bastard wing; **C**, œsophagus; **CA**, right carotid artery; **D**, crop; **DA**, aorta; **E**, keel of sternum; **F**, right auricle; **G**, right ventricle; **HV**, hepatic vein; **H1**, left bile-duct; **H2**, right bile-duct; **I**, distal end of stomach; **IA**, right innominate artery; **IV**, posterior vena cava; **JA**, left innominate artery; **JV**, right jugular vein; **K**, gizzard; **L**, liver; **M**, duodenum; **MD**, mid-digital primary feathers; **MP**, metacarpal primaries; **M1**, preaxial metacarpal; **M2**, middle metacarpal; **M3**, postaxial metacarpal; **N**, cloacal aperture; **N1**, preaxial digit; **O**, bursa Fabricii; **O1**, proximal phalanx of middle digit; **O2**, distal phalanx of middle digit; **P**, pancreas; **PA**, right pectoral artery; **PD**, predigital primary; **PV**, portal vein; **P1**, first pancreatic duct; **P2**, second pancreatic duct; **P3**, third pancreatic duct; **Q**, pygostyle; **R**, rectum; **RC**, radial carpal bone; **RX**, rectrices; **R1**, ulnar digit; **S**, ureter; **SA**; right subclavian artery; **SV**, right anterior vena cava; **T**, rectal diverticulum; **U**, kidney; **UC**, ulnar carpal bone; **V**, pelvis; **W**, lung; **X**, humerus; **Y**, radius; **Z**, ulna. (From Marshall and Hurst.)

there is one toe behind and three in front, but in many woodpeckers there are two in front and two behind, an arrangement which doubtless enables them to cling to the bark of trees more

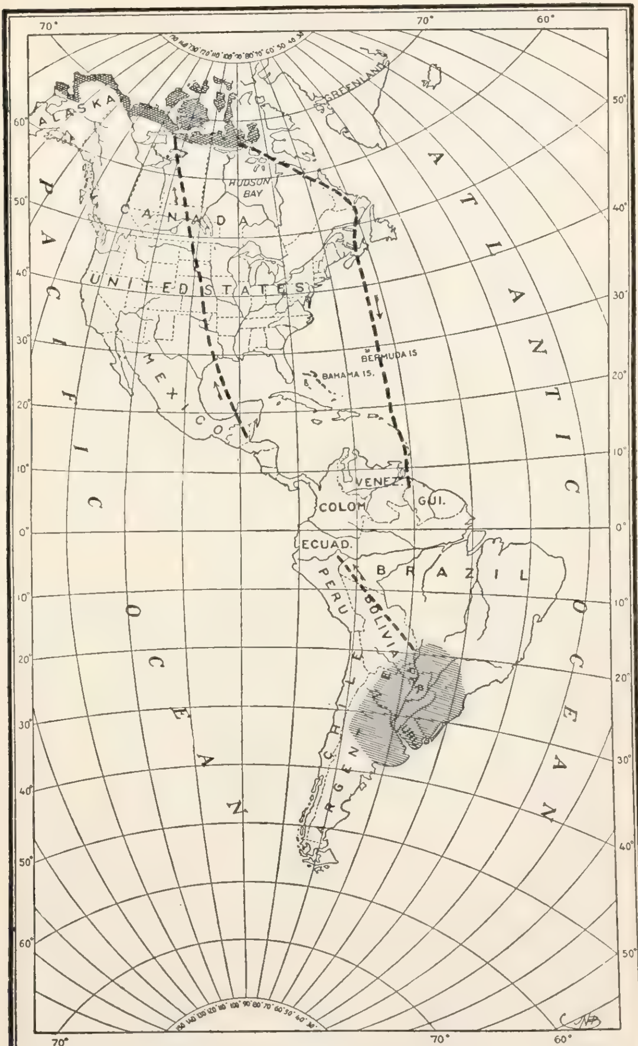

FIG. 218. — Paths of migration of the golden plover. (From Cooke.)

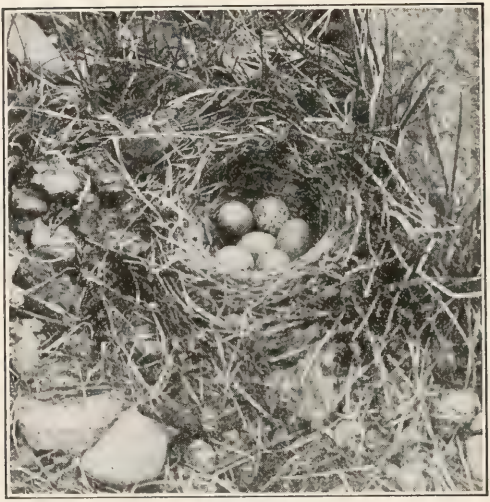

FIG. 219. — Nest of prairie horned lark on the ground in a field. The darkly spotted egg is that of a cowbird. (Photo. by Hegner.)

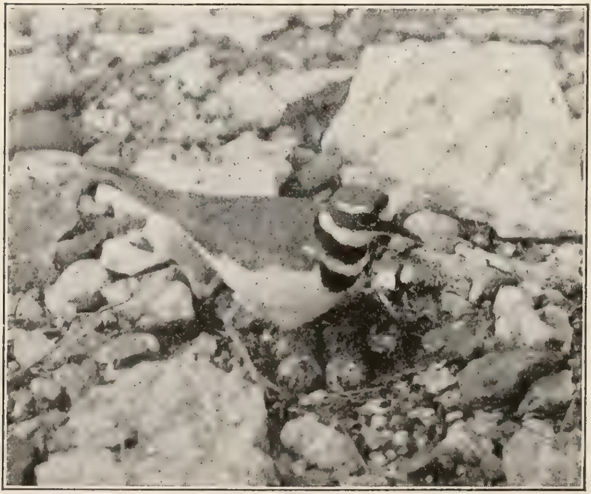

FIG. 220. — Killdeer plover standing over her nest and four eggs among the pebbles near a small stream. (Photo. by Hegner.)

easily. An examination of the bones in a bird's foot shows at once that birds walk on their toes, that is, are digitigrade, and not on the sole (plantigrade), as in man.

Action of Toes while Perching. — When at rest, the birds often maintain themselves for hours perched on a limb, with the toes holding the body upright. This would soon tire the muscles if it were not for a special mechanism which automatically causes the toes to grasp the perch. The tendon which bends the toes passes over the back of the ankle joint. The weight of the body bends this joint, draws the toes around the perch, and automatically holds the bird firmly in place.

Fig. 221. — Eggs of whippoorwill laid on dead leaves on the ground in the woods. (Photo. by Hegner.)

How the Beak is Used. — Birds, like turtles, are toothless, and the jaws are covered by horny sheaths which constitute the beak. The beak of the bird performs many of the functions of human hands: it is used to obtain food, build nests, preen the feathers, care for the young, etc. The bird must be able to move its head freely if the beak is to succeed in accomplishing all these duties. It is able to do this because the neck is comparatively long and the vertebræ in it move easily upon one another.

Beaks are Adapted to Various Purposes. — Just as the feet differ in different birds according to the habits of the species, so the beaks are much modified for particular purposes (Fig. 215).

FIG. 222. — The bank of a stream showing the entrances of a kingfisher's tunnel at the left and that of a bank swallow at the right. (Photo. by Hegner.)

Birds preen themselves by pressing a drop of oil from the oil gland, which lies just above the tail, and spreading it over their

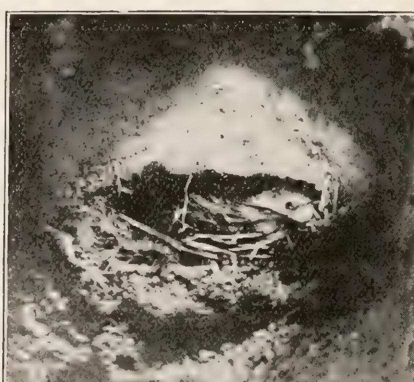

FIG. 223. — Bank swallow on its nest at the end of a tunnel in the bank of a stream. (Photo. by Hegner.)

feathers. Besides this general function beaks are used in many different ways: that of the woodpecker is chisel-shaped and fitted for digging into the wood of trees; the beak of the sparrow that eats seeds is short and thick for crushing its food; insect-eating birds, like the thrush, possess beaks that are longer and not so strong; birds, like the swift, that catch insects in the

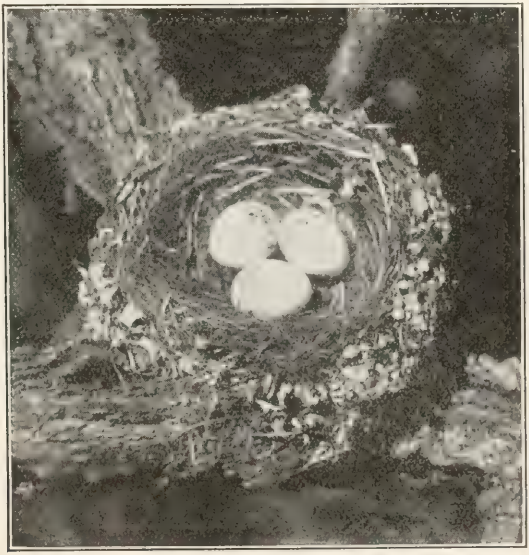

FIG. 224. — Nest and eggs of the wood pewee. The nest was built on a horizontal branch of a tree 15 feet from the ground. (Photo. by Hegner.)

air have small beaks but very capacious mouths; wading birds possess long beaks for obtaining food under water and in the mud; and birds of prey are provided with strong, curved beaks for tearing flesh. These are but a few of the many different forms and uses that might be described.

Birds are Warm-blooded Animals. — The feathers are of the utmost importance to the bird, since flight is impossible without them. While this is their most obvious function, there are several others just as important. Birds and mammals are warm-

blooded animals in contrast to all the rest of the animals, which are cold-blooded. Warm-blooded animals consume so much food that a bodily temperature usually greater than that of the surrounding air is maintained. This heat is the result of the oxidation within the cells, and the temperature is practically constant no matter how warm or cold it is outside. Feathers prevent the body heat from escaping by forming many air spaces at the surface. The temperature of the bird's body ranges from 100° to 112° F., whereas that of man is normally only 98.6° F.

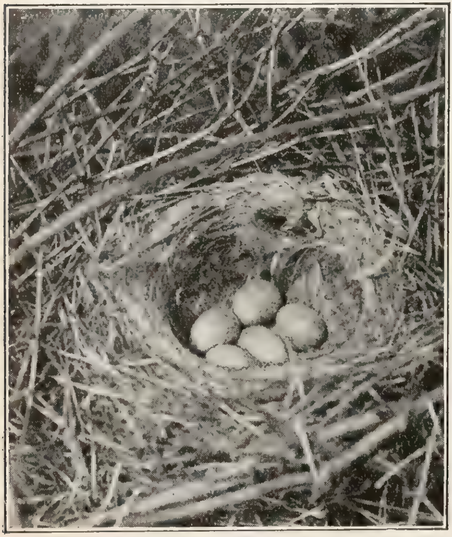

FIG. 225. — Nest and eggs of the white-rumped shrike (butcher bird). The nest was built in a hawthorn tree 10 feet from the ground. (Photo. by Hegner.)

Feathers. — How wonderfully effective feathers are for the purposes for which they are used can easily be determined by examining one in the laboratory (Fig. 216). Feathers are embedded in pits in the skin, the feather follicles. The central axial rod of the feather is the stem, and on each side of this is a vane. The quill is that part of the stem without vanes. If the vane is examined closely, it will be found to consist of a great number of parallel rods, the barbs. Each barb resembles in appearance an entire feather, since on each side there is a row of slender projections, the barbules. Hooklets are present on these barbules. These hooklets hold the barbs together, and thus the entire vane

becomes a pliable but also resistant structure, which is strong but light and admirably adapted for purposes of flight.

Beneath the large feathers are smaller down feathers which have a slender stem and hookless barbs. The down feathers are very effective in preventing the escape of the body heat.

FIG. 226. — Red-tailed hawk about to sit on her eggs. The nest was in a birch tree 40 feet from the ground. The bird is taking her own picture by sitting on a string which was attached to the shutter of a camera placed in a near-by tree. (Photo. by Hegner.)

Certain hairlike feathers occur about the mouth and sometimes on other parts of the body; these are known as filoplumes. Feathers are not embedded in all parts of the skin, but those parts of the body without them are covered by feathers from other regions.

Molting. — All birds change their feathers frequently. The young, when newly hatched, are either naked or covered with down. They soon outgrow this, just as young children outgrow their clothes, and in the course of a week or two true feathers

begin to appear, and only a few spots of down remain to show where the baby clothes still show through the contour feathers.

The first plumage is worn only a short time; then it gives way to a second plumage. The loss of one set of clothing and the acquirement of another is called "molting." In adult birds molting is annual or semi-annual. All birds shed their feathers in the autumn, after they have finished their household duties for the season, and they put on their heavy woolen winter clothing in the shape of a beautiful new set of plumage. In the spring many birds change their clothes again, and at this time acquire the gorgeous ornaments that are everywhere noticeable just before the breeding season, such as the elegant plumes of the snowy heron, known as "aigrettes" (Fig. 261).

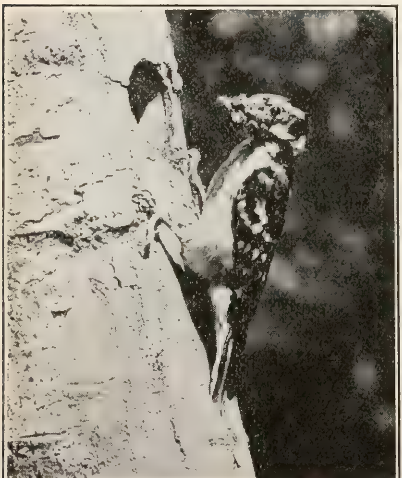

FIG. 227. — Downy woodpecker at entrance to nest-hole in a dead poplar tree. Her bill is filled with insects which she has captured on near-by trees and is about to feed to her young within the hole. (Photo. by Hegner.)

Internal Organs. — Certain peculiarities in the internal organs of birds may be pointed out here (Fig. 217). The *food* is not masticated, as there are no teeth present. It is stored in an enlargement of the œsophagus, the *crop*, where it is macerated. In the *stomach* it is acted upon by digestive juices from a glandular portion and ground up in the muscular *gizzard*. Frequently small stones are swallowed to aid in grinding up the food.

The *heart* is comparatively large, and instead of a ventricle partly divided in two, as in reptiles, there are two entirely sepa-

rate ventricles. Birds are more active than amphibians or reptiles, besides being warm-blooded, and they must therefore have a highly developed heart for producing rapid circulation and an especially favorable means of oxygenating the blood. Accordingly we find the *respiratory system* highly organized. In addition to the *lungs* there are nine large *air sacs* within the body-cavity which are connected with the lungs and which, besides increasing the amount of air in the body, also decrease the specific gravity of the bird and make flying easier. Furthermore, many of the air spaces in the hollow bones communicate with the air sacs.

FIG. 228. — One young cowbird in a vireo's nest. The three young vireos were crowded out by the young cowbird. (Photo. by Hegner.)

Bird Songs and Call Notes. — Connected with the respiratory system is the vocal organ or *syrinx* with which birds produce their call notes and songs. This organ lies just where the windpipe divides, sending a branch to each lung. It is an enlargement of the windpipe containing a valve which vibrates when air is forced out of the lungs and which can be tightened by muscles, thus regulating the number of vibrations and consequently the pitch of the sound produced.

These sounds may be divided into two kinds, call notes and songs. *Call notes* form the principal language of the birds, since anxiety, fear, and other emotions can be expressed by them. *Songs*, on the other hand, are heard most frequently during the nesting season. Usually only the males are able to sing. The importance of learning the call notes and songs of birds

cannot be too strongly emphasized since they are among the most beautiful sounds in nature, and besides, birds are so effectively concealed most of the time by the foliage of the trees that we hear many more than we are able to see.

Bird Migration. — The remarkable powers of locomotion possessed by birds enable them to move from one part of the country to another with comparative ease. As a result, when

FIG. 229. — Nest and eggs of least bittern. The nest was built among the reeds above the water in a marsh. (Photo. by Hegner.)

winter approaches in temperate regions most of the birds gather together in flocks and migrate to the warmer southern countries. Those that remain in one locality throughout the year, like the great horned owl and English sparrow, are called permanent residents; those that pass through on their way south in the autumn and on their way north in the spring, like most of the warblers, are called migrants; and those that leave in the autumn and return the following spring, remaining with us to nest, we call summer residents.

Formerly, birds were supposed to hibernate during the winter in caves, hollow trees, or, in the case of swallows, in the mud at

the bottom of lakes and ponds. This is now known to be incorrect, and when birds disappear in the fall, they depart to spend the winter in a more congenial southern climate.

Migration means moving from one place to another, and the idea of distance is emphasized. Birds are the most famous of all animals from the standpoint of their migrations. As winter approaches in the north temperate zone, they gather together in flocks and move southward, returning on the advent of the following spring. Birds that breed farther north spend the winter in parts of the temperate zone.

FIG. 230. — Nest and eggs of Florida galinule. When disturbed the sitting bird slid down the rushes in the foreground into the waters of the marsh. (Photo. by Hegner.)

One of the most remarkable of all migratory birds is the golden plover. These plovers arrive in the "barren grounds" above the Arctic Circle the first week in June (Fig. 218). In August they fly to Labrador, where they feast on the crowberry and become very fat. After a few weeks, they reach the coast of Nova Scotia, and then set out for South America, over twenty-four hundred miles of ocean. They may or may not visit the Bermuda Islands and the West Indies. After a rest of three or four weeks in the West Indies or northern South America the birds depart and are next heard from on their arrival in southern Brazil and Argentine. Here they spend the summer, from September to March, and then disappear. Apparently they fly over northern South America and Central America, and over the central portion of North America, reaching their

breeding grounds in the Arctic Circle the first week in June. The elliptical course they follow is approximately twenty thousand miles in length, and this remarkable journey is undertaken every year for the sake of spending ten weeks in the bleak, treeless, frozen wastes of the Arctic Region.

Most birds migrate on clear nights at an altitude sometimes of a mile or more. Each species has a more or less definite

FIG. 231. — Nest and eggs of the black tern. The eggs were laid in a slight cavity in the muck of a marsh lined with a few dry stems. (Photo. by Hegner.)

time of migration, and one can predict with some degree of accuracy the date when it will arrive in a given locality. The speed of migration is, as a rule, rather slow, and a daily rate of twenty-five miles is about the average.

During their migrations, birds are often killed in great numbers by striking against objects, such as the Washington Monu-

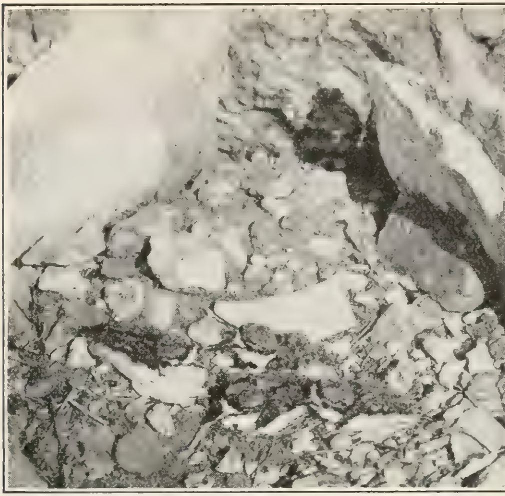

FIG. 232. — Four young killdeers just hatched. They were able to run about as soon as hatched. Notice their resemblance to their surroundings. These young hatched from the eggs shown in Fig. 220. (Photo. by Hegner.)

FIG. 233. — Young blue jays. Young of this type are said to be altricial. They are naked and blind when hatched. (Photo. by Hegner.)

ment, lighthouses, and telegraph wires. Over fifteen hundred birds were killed in one night by dashing against the Statue of Liberty in New York Harbor. Birds may also be driven out to sea or be killed by severe storms.

Many theories have been advanced to account for the migration of birds, such as the temperature and condition of the

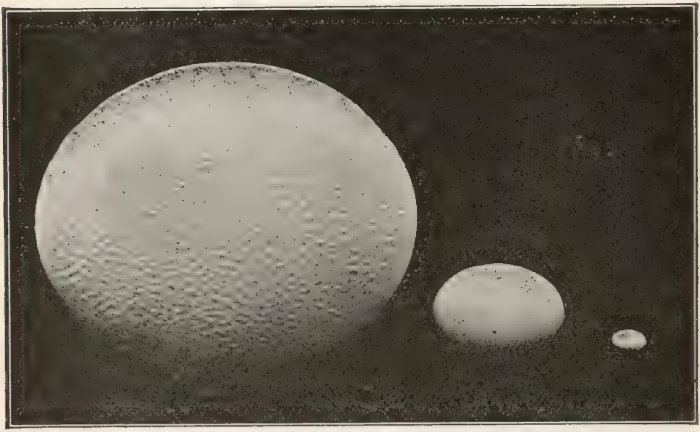

FIG. 234. — Eggs of ostrich, hen, and humming bird, showing comparative size. (Photo. by E. R. Sanborn.)

food supply. Other theories attempt to explain how birds find their way during migration. The best of these seems to be the "follow-the-leader" theory. According to this, birds that have once been over the course find their way by means of landmarks, and the inexperienced birds follow these leaders.

Mating. — Mating takes place soon after the birds return in the spring. A few birds, like the birds of prey, remain mated throughout life, but most of them select new mates each spring.

Nest Building. — The nests are built in almost every conceivable location, and those of one species resemble one another but differ from those built by other species. Some birds, like the prairie horned lark, build a nest on the ground (Fig. 219);

the plovers, such as the killdeer, scrape a little hollow in the ground in a field or near a stream, making very little effort to form a real nest (Fig. 220); and many birds, for example the

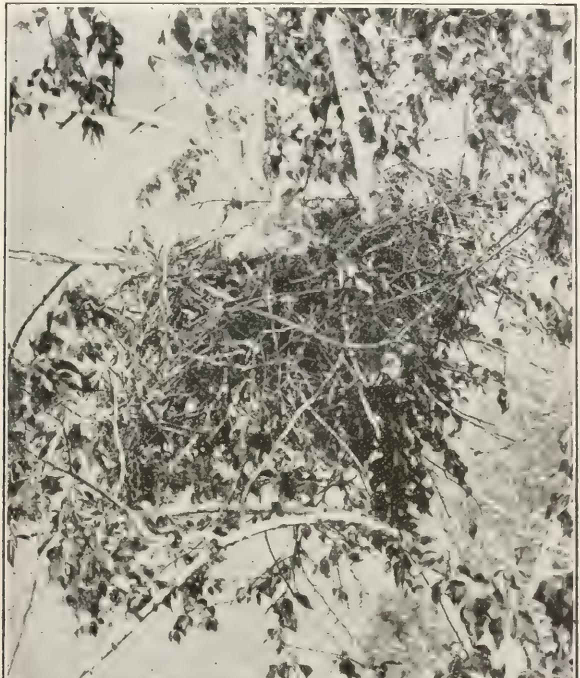

FIG. 235. — Two young red-tailed hawks, 10 days old, in nest shown in Fig. 226. (Photo. by Hegner.)

whippoorwill and certain sea birds, make no nest at all, but lay their eggs on the bare ground (Fig. 221).

A few species make their homes in burrows in the ground; of these the kingfisher (Fig. 222), bank swallow (Fig. 223), and burrowing owl are common examples.

Nests built in bushes or trees must be able to withstand the fury of storms and are consequently more strongly constructed.

Mud, vegetable fibers, bark, twigs, horsehair, and thistledown are common nesting materials (Figs. 224, 225, 226).

The woodpeckers secure a nesting place safe from most intruders by digging a hole in a tree (Fig. 227). No actual nest

FIG. 236 A. — Two young red-tailed hawks 17 days old. One is behind a limb. (Photo. by Hegner.)

is made by them, but the eggs are laid directly upon the chips at the bottom of the hole.

One bird is worthy of special mention; this is the cowbird or lazy bird. The cowbird resembles the European cuckoo in its nesting habits. It does not build a nest at all, but lays its eggs in the nests of other birds (Fig. 219), usually of those smaller than itself, and then leaves them to be cared for by the foster

parents (Fig. 228). Often the young cowbirds are stronger and thus starve out the rightful owners of the nest.

Many birds nest in marshy situations and are consequently very seldom seen by most people. They are the marsh wrens, gallinules, rails, grebes, terns, loons, bitterns, and many others.

FIG. 236 B. — Two young red-tailed hawks 27 days old and almost ready to fly. (Photo. by Hegner.)

Their nests are built of dry rushes and other plants and suspended among the rushes above the water, or are made on the soggy ground of decaying vegetation (Figs. 229, 230, 231).

Precocial and Altricial Birds. — It is necessary to distinguish between precocial and altricial birds in discussing the eggs and

young. The young of precocial birds are able to run about like young chickens soon after they are hatched (Fig. 232). The eggs of these birds must be correspondingly large in order to contain food material (yolk and white) enough to enable the young to reach such an advanced stage in development. The killdeer, nighthawks, bobwhites, and ducks are common precocial birds.

The young of altricial birds, on the other hand, hatch in a very immature condition (Fig. 233) and must remain in the nest a long time until their feathers are grown and they become strong enough to walk or fly. Most of our common birds are of this sort.

Birds' Eggs. — The eggs of birds are covered by a hard shell of calcium carbonate (Fig. 234). Eggs are single cells, their enormous size being due to the accumulation of food material within them. The shell is either pure white, as in many of the birds like woodpeckers and kingfishers that lay eggs in dark places, or variously colored and covered with specks, spots, and lines of different hues. Colored eggs are adapted to their surroundings, since they are less conspicuous amidst the green vegetation than white eggs would be.

Number of Eggs. — The number of eggs laid in a single nest, called a "clutch" or "set," is usually the same for individuals of one species, but differs in different species. The passenger pigeon lays one egg; the mourning dove lays two; the red-tailed hawk two or three; the robin three or four; the blue jay four or five; the bank swallow six; the flicker and kingfisher six or eight; and the game birds, like the bobwhite, from a dozen to twenty.

Incubation. — The eggs must be kept warm or incubated in order to develop; this is accomplished by the bird sitting on them. Sometimes the female alone performs this duty; sometimes both birds take turns; and in a few instances, like that of the ostrich, the male alone incubates the eggs. The period of incubation lasts from ten or twelve days among the smaller birds to over a month in the case of the largest species.

Growth of the Young (Figs. 235, 236 A, 236 B). — The young hatch with a covering of down (precocial birds) or practically naked (altricial birds). They devour large quantities of food, principally insects, and grow rapidly. The feathers gradually grow in, but are often different from those of the parents in color.

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FIG. 237. — The fossil remains of the oldest extinct bird known (Archæopteryx). (From Zittel.)

CHAPTER XXXV

SOME COMMON BIRDS OF NORTH AMERICA

LACK of space prevents us from giving a full account of the twelve thousand or more different kinds of living birds known at the present time, and students must therefore be referred to books concerned only with birds. Of the twelve thousand described species about 850 are known to occur in North America. A single state may be inhabited by three hundred species; for example, 326 different kinds of birds have been recorded from the state of Michigan. The number in any particular locality depends largely upon the amount of water, swamps, and forests in that vicinity; an average number is about 200; 267 have been observed in the vicinity of Ann Arbor, Michigan.

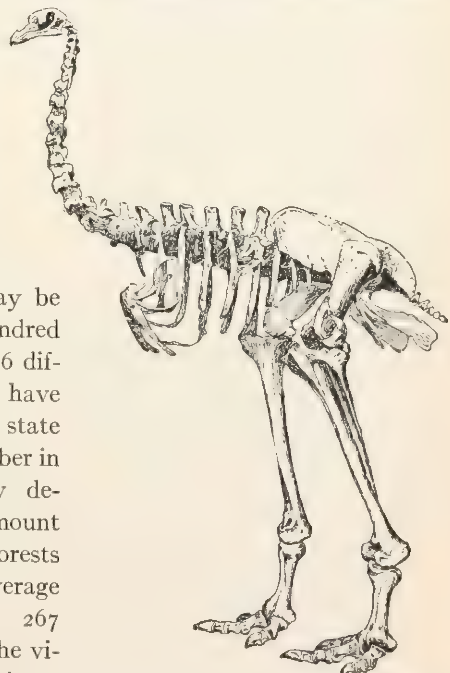

FIG. 238. — Skeleton of the extinct moa. (After Owen.)

Ancient Birds. — The birds that lived on the earth thousands of years ago differed from those alive to-day in many respects. The most ancient of these is the reptile-like bird called

Archæopteryx whose fossil remains were found in the rocks in Bavaria (Fig. 237). Its jaws were provided with teeth, its tail

FIG. 239. — The kiwi, a wingless bird living in New Zealand. (From Evans.)

was long with feathers arranged along the sides, and its wings bore claws. The fossil remains of other toothed birds have

FIG. 240. — A group of penguins or rock-happers. (From Evans.)

been discovered in the earth's crust, notably in the state of Kansas.

The moas (Fig. 238) have probably become extinct within the

past five hundred years. The remains of these peculiar birds have been found in great numbers in caves and refuse heaps in New Zealand, to which country they appear to have been confined. Twenty or thirty species are known from these remains. They range in size from that of a turkey to nearly ten feet high. They were flightless, but possessed enormous hind limbs.

Flightless Birds. — Many birds, like the extinct moas, possess only rudimentary wings and therefore are unable to fly. The ostrich succeeds in escaping many of its enemies by running, but most of the flightless birds are an easy prey for man and other animals. They have either become extinct, like the great auk, or are nearly all exterminated. In South America occur some flightless birds called rheas or New World ostriches because of their resemblance to true ostriches.

FIG. 241 — Pelican. (Photo. by Sanborn.)

Two other kinds of flightless birds are worthy of mention: the kiwis of New Zealand and the penguins of the Antarctic regions. The kiwis (Fig. 239) are very strange-looking because their wings are so small that they are entirely covered by the hairlike body feathers, and the absence of tail feathers gives the bird a peculiar stumpy appearance.

The penguins (Fig. 240) are adapted for life in the water. The fore limbs are modified as paddles for swimming; the feet are webbed; the cold water can be shaken entirely from the

feathers; and a layer of fat just beneath the skin serves to keep in bodily heat. They feed on fishes and other marine animals. On shore they stand erect, side by side. They nest in colonies, laying one or two eggs either among the rocks or in a burrow.

Water Birds. — It is convenient to divide the seventeen orders of Northern American birds into two groups — water birds and land birds. Water birds are those that live near

FIG. 242. — Great blue heron spreading its wing. (Photo. by Hegner.)

ponds and streams or on the seacoast. Most of them spend much of their time swimming about on the surface or wading near shore. Their food consists of water plants, insects, worms, and other small animals captured in the water or extracted from the muddy bottom.

DIVING BIRDS. — The grebes and loons are called diving birds because of their ability to swim under water. Usually these birds are awkward on land since their bodies are built for swimming and their feet are webbed.

Long-winged Swimmers. — The gulls and terns spend a large part of their time in the air and possess long wings. They live near bodies of fresh water, or more often on the seacoast or on islands.

Tube-nosed Swimmers. — These are marine birds with tubular external nostrils, fully webbed toes, and long, narrow

Fig. 243. — Nest and eggs of ruffed grouse among the leaves under a log in the woods. (Photo. by Hegner.)

wings. They are strong fliers, gregarious, and come to land rarely except to lay their eggs. The *wandering albatross* and *stormy petrels* are well-known examples.

Pelicans and Cormorants. — These birds have long legs, long, slender necks, elongated bills, and feet fitted for wading or swimming.

The *pelicans* (Fig. 241) possess a huge membranous pouch between the branches of the lower jaw, with which they scoop up small fish. The common *cormorant*, or shag, occurs on the Atlantic coast of Europe and North America and breeds on the rocky shores of Labrador and Newfoundland. In China and a few other countries cormorants are trained to catch fish and are of considerable value to their owners.

Ducks, Geese, and Swans. — Every one is familiar with these birds, but very few have ever seen their nests, since they

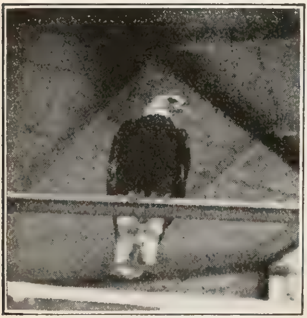

Fig. 244. — Bald eagle. (Photo. by Hegner.)

Fig. 245. — Screech owl at entrance to nest cavity in an oak tree. (Photo. by Hegner.)

are built principally among vegetation in marshy places where people seldom disturb them. The most beautiful of all our ducks is the *wood duck*. This bird which ranges over the entire United States prefers to live near small streams, lakes, and ponds. Its eggs, from six to fifteen in number, are laid in cavities in the trunks or limbs of trees. The wood duck is one of our game birds that is decreasing so rapidly in numbers that it seems on the verge of extinction, and drastic action must be taken by the federal and state governments if this species is not to vanish entirely.

Herons and Bitterns. — The herons and bitterns possess long legs fitted for wading, broad wings, and short tails.

They are found in the warmer regions of the globe and feed chiefly on fishes. The *great blue heron* (Fig. 242) is a large species occurring in all parts of North America. It is about four feet long and has an extent of wings of about six feet. Its large flat nest is built of coarse sticks usually in the top of a high tree; four to six greenish blue eggs are laid.

FLAMINGOES. — The flamingoes are gregarious birds, congregating in thousands on mud flats, where they build their conical mud nests. They are rosy vermilion in general color. One species occurs in Florida.

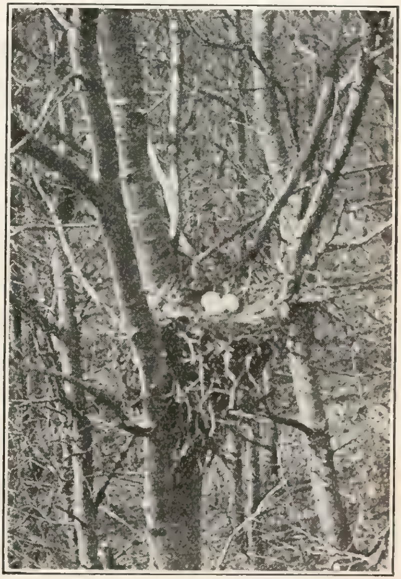

FIG. 246. — Nest and three eggs of the great horned owl. (Photo. by Hegner.)

CRANES, RAILS, AND COOTS. — *Cranes* are large birds with long legs and neck. They live in grassy plains and marshes. *Rails* and coots are also marsh inhabitants, but much smaller. The *coots* are frequently called mud hens, and sometimes hell-divers, because of their ability to dive quickly.

SHORE BIRDS. — Plovers, snipes, and sandpipers are called shore birds because they frequent the shores of ponds, lakes, and streams, where they probe the soft mud for the small animals that constitute their food. The killdeer (Fig. 220) is an interesting species whose name resembles its loud call note. It scratches a slight cavity in the ground near a stream or in a neighboring field and lays four large, dark-spotted eggs. The young can run about soon after hatching. The eggs, young,

FIG. 247. — Belted kingfisher. (Photo. by Hegner.)

and adults are all so much like their surroundings in color that it is very difficult to see them.

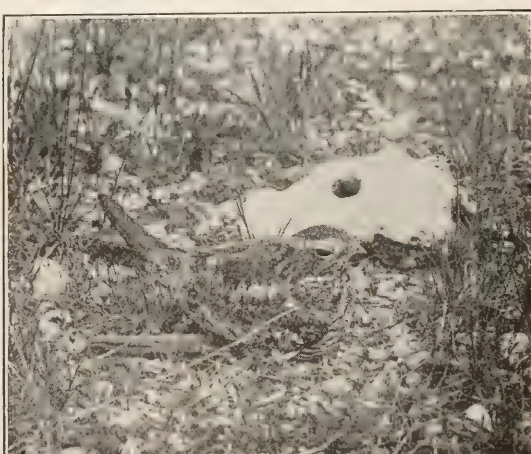

FIG. 248. — Nighthawk sitting on her two eggs which were laid on a pebbly hillside. (Photo. by Hegner.)

Land Birds. — Birds are more abundant in the vicinity of ponds and streams than anywhere else, but many of them live mostly on land, going to water only when thirsty. These may be called land birds.

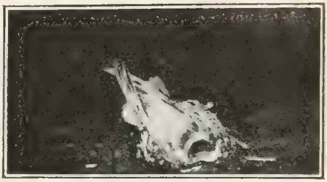

FIG. 249. — Chimney swift sitting on nest which was attached to the inside of a chimney twenty feet from the top. (Photo. by Hegner.)

GAME BIRDS. — The grouse, bobwhites, pheasants, and turkeys are the true game birds. The game birds are, as a rule, terrestrial, but many of them roost or feed in trees. Their nests are usually made on the ground in grass or leaves, and generally a large number of eggs, from six to eighteen, is laid (Fig. 243). The members of one family often remain together as a "covey," and in some species the coveys unite to form large flocks. The wild turkey is the largest American game bird.

FIG. 250. — Chimney swift clinging beside her nest down in a chimney. (Photo. by Hegner.)

PIGEONS AND DOVES. — The mourning dove is a common North American species often mistaken for the passenger pigeon which is now extinct. It makes a flimsy nest of a few twigs and lays two white eggs. The young are naked when born, and are fed by regurgitation.

BIRDS OF PREY. — Vultures, falcons, eagles, hawks, kites, and owls are called birds of prey because of their habit of preying upon small birds and other animals.

The *vultures* live on carrion, and in warm countries are valuable as scavengers. The California vulture or condor is one of the largest of all flying birds.

FIG. 251. — Three young chimney swifts in their nest. (Photo. by Hegner.)

The *falcons*, *hawks*, *eagles*, and *kites* vary in size from the little sparrow hawk to the large bald eagle, our national bird (Fig. 244). Some of them are injurious because they rob the henyard and destroy other birds, but most of them are decidedly

FIG. 252. — Nests of a colony of cliff swallows built on the side of a cliff near a river. (Photo. by Hegner.)

beneficial because they destroy mice, rabbits, and other obnoxious animals.

The *owls* are the nocturnal birds of prey. They possess large rounded heads, strong legs, feet armed with sharp claws, strong hooked bills, large eyes directed forward and surrounded by a radiating disk of feathers, and soft, fluffy plumage which renders them noiseless during flight (Fig. 245). Owls feed upon insects, mice, rats, and other small mammals, birds, and fish. The indigestible parts of the food are cast out of the mouth in the form of pellets. Most species are beneficial to man.

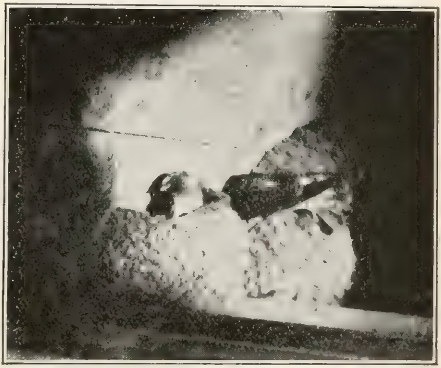

FIG. 253. — Cliff swallows building their nests underneath the eaves of a barn. (Photo. by Hegner.)

The *great horned owl* is one of the largest North American species. It nests in old squirrels' and hawks' nests, in hollow trees, or in crevices in rocky cliffs. Two or three large white eggs are laid (Fig. 246). Its food consists principally of birds and mammals, especially rabbits, and its harmful and beneficial qualities are about equal.

PARROTS. — Only one species of parrot, the Carolina paroquet, occurs in the United States. Parrots and paroquets live in forests and feed on fruits and seeds. They have shrill voices, and can, with few exceptions, be taught to talk. The African parrot learns to talk most readily.

CUCKOOS AND KINGFISHERS. — The majority of cuckoos do not build a nest, but lay their eggs in the nests of other birds. This is not true, however, of the North American species. The black-billed and yellow-billed *cuckoos* of this country are long,

slender birds of solitary habits and with peculiar vocal powers which have given them their common name. The belted kingfisher (Fig. 247) lays its five to eight white eggs at the end of a horizontal hole about six feet deep dug by the birds usually in the bank of a stream. The kingfisher captures small fish by hovering over a stream and then plunging into the water and securing the unsuspecting prey in its bill.

Fig. 254. — Phœbe building a nest above the window on the front porch of a house. (Photo. by Hegner.)

Woodpeckers. — About fifty species of woodpeckers occur in North America. The downy (Fig. 227), hairy, and red-headed woodpeckers, the flicker, and the yellow-bellied sapsucker are the best known. Woodpeckers use their chisel-shaped bills for excavating holes in trees, at the bottom of which their eggs are laid, or for digging out grubs from beneath the bark. Most of them are of great benefit because of the insects they destroy, but the yellow-bellied sapsucker is harmful, since it eats the cambium of trees and sucks sap.

Nighthawks, Whippoorwills, Swifts, and Humming Birds. — The *whippoorwill* inhabits the woods and thickets of eastern North America. It is most active after sundown and early in the morning, when it captures its insect food on the wing. The two eggs are laid on the leaves in the woods (Fig. 221).

The *nighthawk* (Fig. 248) has a range similar to that of the *whippoorwill*. During the day it perches on a limb, fence

post, or on the ground, but in the evening it mounts into the air after its insect prey. The two eggs are laid on the bare ground, usually on a hillside or in an open field; often they are deposited on the gravel roofs of city buildings.

FIG. 255. — A family of bluebirds. Three of the young are on the stick near the father bird. The mother bird is on top of the fence post. (Photo. by Hegner.)

The *humming birds*, which are confined to the New World, have been appropriately called feathered gems, or, according to Audubon, " glittering fragments of the rainbow." Only one species, the ruby-throated humming bird, is found east of the Mississippi River. This beautiful little bird is only three and three-quarters inches in length. It hovers before flowers, from which it obtains nectar, small insects, and spiders. The nest, which is saddled on the limb of a tree, is made of plant down and

so covered with lichens as to resemble its surroundings very closely. Two tiny eggs are laid (Fig. 234). The young are fed by regurgitation.

The *chimney swift* breeds commonly in eastern North America. This species formerly made its nest in hollow trees, but now usually frequents chimneys. When in the open air, it is always on the wing, catching insects or gathering twigs from the dead branches of trees for its nest. The twigs are glued together with

FIG. 256. — Vesper sparrow on nest in a field. (Photo. by Hegner.)

saliva and firmly fastened to the inside of the chimney, forming a cup-shaped nest (Figs. 249, 250, 251). Certain species of Chinese swifts make nests entirely of a secretion from the salivary glands, producing the birds' nests eaten for food in China.

PERCHING BIRDS. — Over one half of the twelve thousand species of birds belong to this group. They are divided into sixty-four families, twenty-five of which have representatives in this country. It is impossible to give an adequate account of them here because of lack of space, so the student is urged to refer to books devoted especially to birds. Some of the common

birds belonging to the order of perching birds are the flycatchers, larks, crows and jays, blackbirds and orioles, sparrows, swallows, warblers, wrens, thrushes, and bluebirds. The accompanying photographs illustrate phases of the home life of some of these birds (Figs. 252–256).

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(See also end of Chapter XXXIV.)

CHAPTER XXXVI

THE RELATIONS OF BIRDS TO MAN

Birds are principally beneficial to mankind. They are things of beauty and add happiness to our lives by their songs. They are largely responsible for the destruction of insect pests and other obnoxious animals, and they destroy countless numbers of weed seeds. The value of domesticated birds as producers of meat, eggs, and feathers is estimated in millions of dollars.

Commercial Value. — With the exception of the domesticated species, birds are now of very little commercial value. In some localities they are persecuted to a considerable extent for their eggs, which are used as food. This is true of certain gulls, terns, herons, murres, ducks, and albatrosses. Egging is not carried on now as much as formerly, since many of the colonies of birds have been driven away from their breeding places, or the government has prohibited the practice. In 1854 more than five hundred thousand murres' eggs were collected on the Farallone Islands and sold in the markets of San Francisco in two months.

Game birds have been and still are in certain localities a common article of food. Most of them, however, have been so persistently hunted by sportsmen and market men that they are now of no great commercial importance. Several species, like the wood duck and heath hen, have been brought to the verge of extinction. The repeating shotgun, introduction of cold-storage methods, and easy transportation facilities soon depleted the vast flocks of prairie chickens and other game birds of the Middle West. One New York dealer in 1864 received twenty tons of these birds in one consignment. The

hunting and transportation of game birds is now regulated by law in most localities.

The use of birds' skins and feathers as ornaments has been for many years a source of income for many hunters, middlemen, and milliners. Laws and public sentiment are slowly overcoming the barbarous custom of killing birds for their plumes, and it is hoped that the women of the country will soon cease to demand hats trimmed with the remains of birds.

Ostriches are now commonly reared for their feathers, and there is no more objection to the use of their plumes for ornament than there is to the use of hens' eggs for food. Ostrich feathers are now procured almost entirely from domesticated birds (Fig. 257). In 1904 there were in South Africa over three hundred and fifty thousand tame ostriches which yielded an annual income of about $18 each. Ostrich farming is now successfully carried on in California, Arizona, Arkansas, North Carolina, and Florida. The feathers are clipped without pain to the birds; those from a single adult weigh about one pound. Ostriches in the natural state live in desert regions and travel about in groups, usually of from four to twenty. They are very suspicious and flee from any signs of danger. Their speed is remarkable, reaching sixty miles an hour, and their single stride may measure more than twenty-five feet.

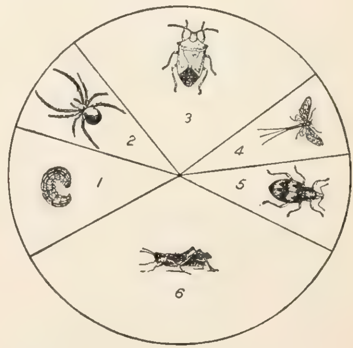
FIG. 257. — Ostrich. (From Evans.)

The Value of Birds as Destroyers of Injurious Animals. — Within the past two decades detailed investigations have been

carried on by the United States Department of Agriculture, state governments, and private parties in order to learn the relations of birds to man with regard to the destruction of injurious animals. The results of these researches may be found in government publications or in books such as Weed and Dearborn's *Birds in their Relation to Man*, and Forbush's *Useful Birds and their Protection.*

NESTLING

FIG. 258. — Food of nestling house wren.



ADULT.

FIG. 259. — Food of adult house wren. (U. S. Dept. of Agric.)

A very large proportion of the food of birds consists of insects. Figures 258 and 259 show diagrammatically the food of nestling and adult house wrens, birds that are very common about gardens. Practically all of the insects devoured by birds are injurious to plants or animals and consequently harmful to man.

Another large element in the food of birds consists of small mammals, such as field mice, ground squirrels, and rabbits. For many years hawks, owls, and other birds of prey have been killed whenever possible, because they were supposed to be injurious on account of the poultry and game birds they captured. Careful investigations have shown, however, that at least six species are entirely beneficial; that the majority (over thirty

species) are chiefly beneficial; that seven species are as beneficial as they are harmful; and that only the gyrfalcons, duck hawk, sharp-shinned hawk, Cooper's hawk, and goshawk are harmful.

As examples of beneficial birds of prey may be mentioned (1) the rough-leg hawk, which feeds almost entirely on meadow mice during its six months' sojourn in the United States, (2) the red-tailed hawk, or "hen hawk," sixty-six per cent of whose food consists of injurious mammals and only seven per cent of poultry, and (3) the golden eagle, which is highly beneficial in certain localities because of the noxious rodents it destroys. The Cooper's hawk is the real "chicken hawk"; its food is made up largely of poultry, pigeons, and wild birds, but it also includes the harmful English sparrows.

The beneficial qualities of birds are well shown by Dr. S. D. Judd from a seven years' study of conditions on a small farm near Marshall Hall, Maryland. Modern methods of investigation led Dr. Judd to the following conclusions: —

"At Marshall Hall the English sparrow, the sharp-shinned, and Cooper hawks, and the great horned owl are, as everywhere, inimical to the farmers' interests and should be killed at every opportunity. The sapsucker punctures orchard trees extensively and should be shot. The study of the crow is unfavorable in results so far as these particular farms are concerned, partly because of special conditions. Its work in removing carrion and destroying insects is serviceable, but it does damage to game, poultry, fruit, and grain that more than counterbalances this good, and it should be reduced in numbers. The crow blackbird appears to be purely beneficial to these farms during the breeding season and feeds extensively on weed seed during migration, but at the latter time it is very injurious to grain. More detailed observations are necessary to determine its proper status at Marshall Hall.

"The remaining species probably do more good than harm, and except under unusual conditions should receive encourage-

ment by the owners of the farms. Certain species, such as flycatchers, swallows, and warblers, prey to some extent upon useful parasitic insects, but, on the whole, the habits of the insectivorous birds are productive of considerable good. Together with the vireos, cuckoos, and woodpeckers (exclusive of the sapsuckers), they are the most valuable conservators of foliage on the farms. The quail, meadow lark, orchard oriole, mocking bird, house wren, grasshopper sparrow, and chipping sparrow feed on insects of the cultivated fields, particularly during the breeding season, when the nestlings of practically all species eat enormous numbers of caterpillars and grasshoppers.

"The most evident service is the wholesale destruction of weed seed. Even if birds were useful in no other way, their preservation would still be desirable, since in destroying large quantities of weed seed they array themselves on the side of the Marshall Hall farmer against invaders that dispute with him, inch by inch, the possession of his fields. The most active weed destroyers are the quail, dove, cowbird, red-winged blackbird, meadow lark, and a dozen species of native sparrows. The utility of these species in destroying weed seed is probably at least as great wherever the birds may be found as investigation has shown it to be at Marshall Hall."

Domesticated Birds. — Birds have for many centuries been under the control of man, and have produced for him hundreds of millions of dollars' worth of food and feathers every year. The *common hen* was probably derived from the red jungle fowl of northeastern and central India. The varieties of chickens that have been derived from this species are almost infinite.

The *domestic pigeons* are descendants of the wild, blue-rock pigeon which ranges from Europe through the Mediterranean countries to central Asia and China. Breeders have produced over a score of varieties from this ancestral species, such as carriers, pouters, fantails, and tumblers. Young pigeons, called squabs, constitute a valuable article of food.

Of less importance are the geese, ducks, turkeys, peacocks,

swans, and guinea fowls. The *geese* are supposed to be derived from the graylag goose, which at the present time nests in the northern British Islands. Most of our domestic breeds of *ducks* have sprung from the mallard. This beautiful bird inhabits both North America and temperate Europe and Asia. The common *peacock* of the Indian peninsula, Ceylon, and Assam has been domesticated at least from the time of Solomon. It has been distributed by man over most of the world. The *swan* is, like the peacock, used now chiefly as an ornament. The mute swan of Central Europe and Central Asia is the common domesticated species. The *guinea fowl* is a native of West Africa. Farmers usually keep a few of them to "frighten away the hawks."

The *turkey* is a domesticated bird that has been brought under control within the past four centuries. Our Puritan ancestors found the wild turkey abundant in New England. It was introduced into Europe early in the sixteenth century and soon became a valuable domestic animal. In its wild state, it is now almost extinct except in some of the remoter localities. Our domestic turkeys are descendants of the Mexican wild turkey.

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(See also end of Chapters XXXIV and XXXV.)

CHAPTER XXXVII

BIRD PROTECTION[1]

It has been evident for some time that the number of birds has been rapidly decreasing, and efforts have been made to learn the cause of this so that protective measures could be undertaken. The enemies of birds are chiefly man and other animals.

1. The Destruction of Birds

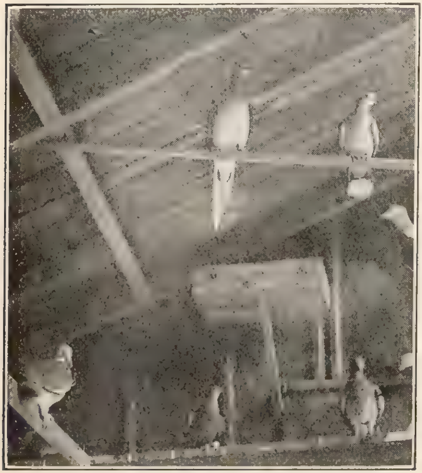

Fig. 260. — Passenger pigeon. (The bird with the long tail.) (Photo. by Hegner.)

The Destruction of Birds by Man. — Man is responsible for the extinction of many species of birds or for their disappearance from great tracts of country. He cuts down the forest and drives out the larger wood birds. He destroys the birds that injure his crops or flocks. He introduces animals which destroy birds, and he shoots for food, money, or sport. It is only since civilized man reached this country that the great auk has become extinct, and that the passenger pigeon (Fig. 260), which roamed in

[1] A large part of this chapter is quoted direct from Forbush's *Useful Birds and their Protection.*

countless millions over our continent, has been swept away. It is since then that the prairie chicken, once found in the east, and so plentiful in Kentucky that it was considered fit food for slaves and swine only, has been pushed toward the far West. The wild turkey has been nearly driven out of the Atlantic States by man. The white egret and the Carolina parrot have almost disappeared. The bartramian sandpiper or upland plover, the wood duck, and the woodcock must follow if not fully protected. Man exterminates birds for money, little recking that he is killing the goose that lays the golden egg.

The greatest enemies of game birds, and, therefore, the greatest factors in their extermination, are the epicures, — the people who buy birds to eat. The market men merely supply the existing demand. The call for game birds has been so insistent and the price paid for them so extravagant that the market men have often organized to defeat legislation for the protection of game. Observing people who have frequented the markets have read from the butcher's stall the story of the decrease of game birds. Within thirty years, tons of passenger pigeons have stood in barrels in the Boston market, and men now living can remember when the eastern markets were glutted with quail and prairie chickens. The war of extermination waged on game birds is a blot on the history of American civilization. It is paralleled only by the destruction of birds for millinery purposes, which has some shockingly cruel aspects.

Here again the dealers — the milliners — are not so much to blame as the public, for the former cater to the wants of women only as fashion dictates. Though civilized we still cling to our rings, beads, and feathers, — the ornaments of the savage. Within thirty-five years the skins of bluebirds, scarlet tanagers, and Baltimore orioles have been in good demand in Massachusetts for hat ornaments.

The brutal savagery which is characteristic of this phase of bird destruction has been well illustrated in the extermination of the egrets of the United States (Fig. 261). Twenty-five

years ago these beautiful birds were abundant in some Southern States; stragglers occasionally came north as far as New England. They are shy birds during most of the year, feeding chiefly in deep swamps and along lonely watercourses. In the breeding season they gather into heronries, commonly called "rookeries," where they build their nests. Then much of their shyness disappears under the stress of providing for and protecting their young. Unfortunately for them, their nuptial plumes are perfect in the breeding season. Fashion demanded the plumes. Nesting time was the plume hunter's opportunity. There was little difficulty, then, in securing the birds by shooting them when they were sitting on the nests or hovering over their helpless young. So the old birds were shot, the plumes stripped from their backs, and the young left to starve in the nests or to become the prey of hawks, crows, or vultures.

Fig. 261. — Egret, nest, and young. (From Peabody and Hunt.)

Visitors in Florida, in 1878, observed great flights of these birds along the lakes and rivers of the southern counties. One heronry was estimated to contain three million birds. Ten years later they were rare everywhere, and now they are practically extirpated. They have been pursued along the coasts of Mexico and into Central and South America. The search is extending into all countries where they may be found. Half-savage Indians and negroes are enlisted in the slaughter, supplied with guns and ammunition, and sent wherever they can

find the birds. The misery and suffering entailed can be imagined. Thus are the "stub" plumes, "aigrettes," and "ospreys" procured. They are not manufactured, and whatever their color when sold, they were originally stripped from the back, head, or neck of some white heron or egret. The absolute extinction of these plume-bearing species is assured unless women will stop wearing the plumes.

A similar slaughter took place among the sea birds along the Atlantic coasts. The birds were shot down on their breeding grounds and their wings cut off. Many human lives have been lost by reason of this nefarious business. In 1905 a warden employed by the National Association of Audubon Societies to protect the birds was murdered by plume hunters. The reader will be spared further details of this barbarous trade.

The number of birds killed in the United States each year before the business was checked by law and public sentiment cannot be estimated, but some figures can be given. A single local taxidermist handled thirty thousand bird skins in one year. A collector brought back eleven thousand skins from a three months' trip. About seventy thousand bird skins were sent to New York from a small district on Long Island in about four months. American bird skins were shipped to London and Paris. We may judge of the demand there for birds from the fact that from one auction room in London there were sold in three months over four hundred thousand bird skins from America and over three hundred and fifty thousand from India. One New York firm had a contract to supply forty thousand skins to a Paris firm.

The danger to birds multiples with the increase of population. Gunners and sportsmen shoot birds mainly to supply the markets or for recreation; but many persons shoot birds, large or small, merely for sport or practice. Certain kinds of foreigners shoot small birds for sport, and eat them. These people go out in squads, and each man shoots at every bird within range, whether sitting or flying.

Boys with shotguns, air rifles, and various destructive weapons, shoot at anything that offers a fair mark. The improvement in firearms and the reduction in their price go hand in hand with the constant increase in the number of people able to bear arms, the augmentation of the number of crack shots, and the accession to the number of dogs trained to hunt birds.

Snares are still much used, even where forbidden by law. Children, especially boys, destroy the nests and eggs of birds, thus constituting a considerable check on bird increase. The mania for collecting birds' eggs is widespread. Some boys use the nests of birds for targets and their eggs for missiles in the same spirit in which the same young savages murder the toads about a pond.

There are many indirect ways in which man reduces the numbers of birds. Marshes are drained, and the sustenance of marsh birds destroyed. Reservoirs are made, and the haunts of land birds overflowed. The building of dams for manufacturing purposes holds back the waters of rivers, so that heavy rainfalls in the breeding season flood the nests of many marsh birds, destroying eggs and young. Thus rails, bitterns, and marsh wrens are drowned or driven away. Thousands of birds and their nests are burned by fires in the woods. Swifts are sometimes suffocated in numbers by coal fires built in nesting time. Lighthouses and electric light towers are ob-

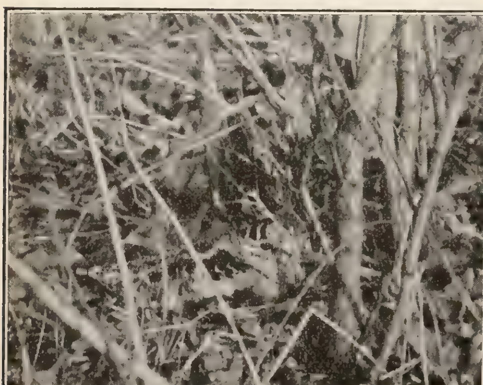

Fig. 262. — Woodcock on nest. (Photo. by Hegner.)

stacles on which many birds are dashed to death in their nocturnal migrations. Telegraph, electric light, trolley car, and telephone wires are all deadly and their number is constantly increasing. Thousands of woodcocks (Fig. 262) and many other birds are killed by flying against them. Wire fences are nearly as fatal to grouse and other low-flying birds.

Last but perhaps not least among the causes which decrease the number of birds about the centers of population there must be enumerated the clearing up of underbrush, shrubbery, vines, and thickets. Many birds of the tangle are driven out when this cover is destroyed and replaced by well-kept lawns and fields.

FIG. 263. — Cat with bird in its mouth. (After Forbush.)

Cats. — We have already introduced into this country a terrible scourge to birds, — the domestic cat (Fig. 263). The statement that the mature cat in good hunting ground kills, on the average, fifty birds a year, is certainly within bounds. Kittens and half-grown cats do not catch many birds, but the old cat that wanders off into the fields and woods is terribly destructive. John Burroughs says that cats probably destroy more birds than all other animals combined.

Squirrels. — Some individual squirrels are habitual nest robbers. This includes all species, but the red squirrel is the worst culprit. Where squirrels have the nest-robbing habit, they may do more harm among birds than any other mammal except the cat. They are active, can climb to almost any bird's nest, and can defend themselves when attacked by the parent birds. Red squirrels and gray squirrels will rob nests either on the ground or in trees, taking eggs or young as they find them. The chipmunk usually molests only those nests that are on or near the ground.

Rats and Mice. — Rats and mice kill some birds. Probably the tree-climbing, white-footed or deer mouse is one of the greatest enemies that birds have among these smaller mammals, but under natural conditions it is held in check by owls.

Hawks. — A very few species of hawks are probably the most destructive native natural enemies of birds. All other hawks kill comparatively few. The sparrow hawk, a great insect killer, kills fewer birds than the others, and is regarded as a friend to the farmer; but there are three species of pernicious hawks: the American goshawk, the Cooper's hawk, and the sharp-shinned hawk. The goshawk is an uncommon or periodical winter visitant, but the other two are fairly common, and individually are probably the most destructive of all the natural enemies of birds. They are slaty or bluish above, with rather short, rounded wings, and long tails. When flying at any height, they progress by alternate periods of flapping and soaring. They may be known by their shape and by their manner of flight.

Owls. — All the owls kill birds, but most species kill but few. They live mainly on mammals, particularly rodents like mice, rabbits, and hares, on the increase of which they constitute an effectual check.

Crows and Jays. — The crows, jays, and magpies have acquired a world-wide reputation as nest robbers. The common crow and the blue jay manage to live up to their reputation.

The American crow is a most deadly enemy to birds from the size of the chipping sparrow to that of the night heron, ruffed grouse, and the black duck, for it continually steals the eggs and young of such birds and poultry.

The well-known blue jay is destructive to the eggs of the smaller birds, whose nests it robs systematically, and it has frequently been seen to kill the young. The robin and other larger birds will drive the jay away from their nests, but it often succeeds in robbing them by stealth. Vireos, warblers, and sparrows it regards very little, and plunders their nests without noticing their agonized cries.

These birds, on the other hand, possess many useful traits. Crows are valuable as grasshopper killers, and they are destructive to the gypsy moth. Jays eat the eggs of the tent-caterpillar moth and the larvæ of the gypsy moth and other hairy caterpillars.

The English Sparrow. — The house or "English" sparrow is the only one of the smaller birds that has repeatedly been seen to destroy the nests of other birds, break their eggs, kill their young, mob them, and drive them away from their homes. It occupies the houses of bluebirds, martins, swallows, and wrens, and the nests of barn swallows, cliff swallows, and bank swallows, and by persistency and force of numbers drives the owners away.

Snakes. — All the common snakes, except, perhaps, the little green snake, eat birds and eggs. Birds exhibit great dread of snakes, but the brown thrasher or the catbird will attack them bravely in defense of their young. Some birds seem to be incapacitated by terror when a snake appears at the nest, and are rendered incapable of any effectual defense. The common black snake is the greatest enemy the birds have among native snakes, for it climbs trees with the greatest ease, and is so swift that it is able to catch young birds when they first leave the nest and sometimes it strikes down an anxious parent.

2. The Protection of Birds

Protection from Natural Enemies. — In Part 1 of this chapter we have considered the enemies of birds. One method of protecting birds is to destroy their natural enemies whenever possible. It is rather difficult to decide whether certain bird enemies should be killed or not, but there can be no doubt as to the destruction of cats and English sparrows. Other enemies, like Cooper's hawks and sharp-shinned hawks, should be killed on sight. Many animals, such as squirrels, crows, and jays, which rob birds' nests or kill the young, should not be exterminated, but their numbers should be reduced.

Protection from Man. — The first and most important step in protecting birds from their human enemies is to create a public sentiment in favor of birds, by teaching their value and the necessity for conserving them. But many people cannot be taught these things and must be prevented by law from destroying birds. The Biological Survey of the United States Department of Agriculture has published and is constantly distributing many reports on the food habits and utility of birds. The Audubon societies and the National Association of Audubon Societies send out illustrated leaflets concerning birds to teachers and others, and is directly interested in getting legislatures to pass proper laws for the protection of birds. Many other societies such as those for the Prevention of Cruelty to Animals, the American Rescue League, the League of American Sportsmen, and the Agassiz Associations also lend their influence in the same direction.

Many laws have been passed protecting song birds, and others are on the statute books protecting game birds during certain seasons or for a period of years. Besides this, tracts of land have been purchased in various parts of the country for the purpose of providing a refuge for birds and other animals. Reservations of this sort should be maintained in every state in the Union if we wish to save our wild animals from extinction (see Chap. XLI).

3. Methods of Attracting Birds

It is usually an easy matter to attract wild birds to the vicinity of one's home. First of all, birds need food before they can

Fig. 264. — Plants that attract birds. (After Forbush.)

carry on any of their nesting activities. The food of birds consists largely of insects, seeds, and berries. Insects are present almost everywhere and, as a rule, seeds are abundant; conse-

quently, trees or shrubs that bear berries eaten by birds should be planted (Fig. 264). Among these may be mentioned the mountain ash, sumac, raspberries, elder, virginia creeper, mulberry, barberry, cherry, dogwood, and red cedar.

In winter the permanent residents or winter visitors sometimes have difficulty in finding enough food to keep them warm and will welcome any help from human friends. Grain scattered

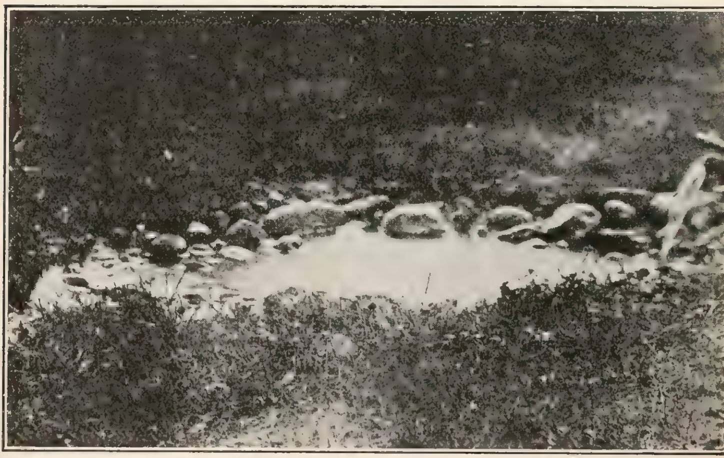

FIG. 265. — A bird bath. (Photo. by Hegner.)

about on the snow will attract tree sparrows, juncos, and others. Pieces of pork rind or of suet tied to a limb of a tree will tempt the appetites of woodpeckers, nuthatches, and chickadees.

Water is needed by birds both to drink and for bathing, of which they are very fond. This is especially true during the hotter days of summer. If there is a water tap on the lawn, a very good bird bath can be constructed by making an indentation a few inches deep and three feet long and lining this with round stones set in clay (Fig. 265). In such a place as this many different kinds of birds make their toilets on warm summer days.

Bird Houses. — Many birds make their homes in hollows in trees, fence posts, and similar places. Where no nesting sites of this kind occur, houses should be made and put up to attract those birds that otherwise would seek homes elsewhere.

Bird houses should be made of rough, weathered lumber and should not be painted. They may be covered with bark, but care must be taken to have the bark tightly fastened to the boards, or it will furnish excellent homes for insect pests. Lumber with the bark left on is extremely useful and makes houses of the best type.

FIG. 266. — Clay bird houses. (Photo. by Hegner.)

A section of the hollow limb of a tree makes a home most nearly like that which the bird naturally uses. This section should be plugged at both ends and an entrance made in the side. When a hollow limb is not obtainable, a limb may be bored out. Where pottery is taught, excellent houses of clay may be made which will serve admirably for wrens (Fig. 266).

The position of the house is important and should be considered for each bird. The boxes must be well fastened in a sheltered position, shielded both from the sun and from too close observation. The natural enemies must also be considered,

and plans must be made to keep the cats, sparrows, and jays from disturbing the nests. If the house is in a tree or on a post, a little barbed wire coiled around the post about five feet below it will protect it from cats; jays and sparrows cannot get at the nest if there is no perch.

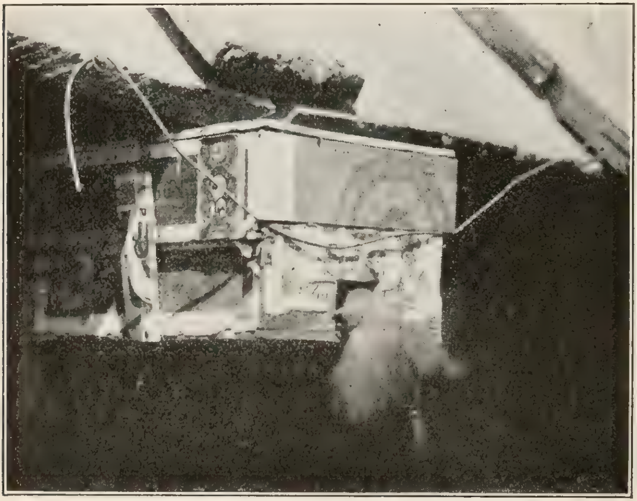

FIG. 267. — House wren carrying a stick into a nesting box. (Photo. by Hegner.)

The *wren*, although a very small bird, can use a relatively large house (Fig. 267). It should be about 8 × 6 × 6 inches inside. Near the top of one end an opening $1\frac{1}{4}$ inches in diameter should be made for the entrance. A perch is not necessary, and is better left off, as it allows the English sparrows and other depredators to get at the contents (Fig. 268). The house should be placed in a tree or on the side of a building 7 to 15 feet from the ground. It is safest when nailed to a building where it is out of reach of cats.

The little *black-capped chickadee* is almost exactly the size of the wren, but uses a smaller house. A box 3 × 3 × 7 inches

inside, with an entrance $1\frac{1}{4}$ inches in diameter on one side near the top, makes a very acceptable chickadee home. This house should be placed with its long diameter perpendicular to the earth, in a tree or against a building, about 10 feet from the ground.

FIG. 268. — Nest of house wren in nesting box shown in Fig. 267. (Photo. by Hegner.)

The chickadee in its natural haunts rears its young in the hollow of a tree. The nest is made of soft moss, a few feathers, and the hairs of different animals. From six to ten eggs are laid — pure white with a reddish tint, and spotted with reddish brown at the larger end.

FIG. 269. — Bluebird with a grasshopper for its young. (Photo. by Hegner.)

Chickadees are with us the entire year. Their nests are built about the first of May, and two broods may be reared in a season.

The *bluebird* is larger than the chickadee and wren, and needs a larger home. Its house should be $10 \times 6 \times 6$ inches inside. The entrance is in one end, from 2 to

$2\frac{1}{2}$ inches in diameter. Place the house in a position similar to that of the wren. The top of a post is a favorable site.

The bluebird's natural nesting place is a hollow in a stump, fence post, or tree (Fig. 269). It often makes use of a tin can lodged in a fence corner, and is partial to the old deserted nest holes of woodpeckers. The nest consists of soft grasses. Five light blue eggs are usually laid, and two or three broods are reared during the nesting season.

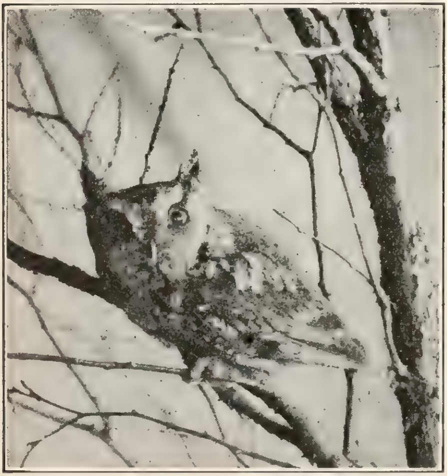

FIG. 270. — Screech owl. (Photo. by Hegner.)

Bluebirds may be looked for about the last of March. They mate about the last week in April. Bird houses for them should therefore be in place by the end of March. Care must be taken to protect the bluebirds from the English sparrows, which are ever ready to drive out the real owners and appropriate the house.

Unlike the other birds mentioned in this article, the *martin* is sociable and seems to enjoy the company of its fellows. Its house may be built with compartments which will allow several pairs to occupy it at the same time. The compartments should be about $9 \times 7 \times 7$ inches inside. The entrances should be $2\frac{1}{2}$ inches in diameter, near the top of the compartments. Many elaborate and beautiful houses are possible, as the martins are not afraid of homes constructed by human beings. The house should be placed on top of a building or on a tall post.

Suitable nesting places for the screech owl (Fig. 270) are not

common, and a bird house, if carefully made, may attract a tenant. It should be $16 \times 8 \times 8$ inches inside, and may have the top left open for an entrance or a hole 4 inches in diameter in one side near the top. Screech owls do not build nests, but lay their eggs on the rubbish found at the bottom of holes in trees. It would therefore be well to line the house with leaves to tempt any visitors to remain. The sides of the house should be covered with bark to make it resemble the tree in which it is placed.

REFERENCES

See end of Chapters XXXIV–XXXVI.

CHAPTER XXXVIII

THE STRUCTURE AND ACTIVITIES OF MAMMALS

Mammals are popularly known as "animals" or beasts. We are all familiar with the domesticated species such as the dog, cat, horse, cow, etc. and with many of the wild forms. The term mammals was applied to the group because the young, which are born in a very immature condition, are fed with milk from the mammary glands of the mother. There are about 7500 species of living mammals, but only a small proportion of these occur in this country. Mammals range in size from the mouse at one extreme to the whale at the other extreme. Among the simpler species are the egg-laying mammals of Australia and the opossum and kangaroo which carry their young about with them in a pouch. Other well-known species are the moles, shrews, bats, dogs, cats, seals, rabbits, rats, ant eaters, armadillos, camels, deer, horses, elephants, whales, monkeys, apes, and man.

Habitats. — There is great diversity among the members of the phylum Mammalia, due chiefly to their various modes of life. Most of them live on the ground, but many are aquatic, others arboreal, and a few aërial in habit. The whales, dolphins, seals, walruses, and sea cows are aquatic, living almost without exception in the sea. They are not aquatic in the same sense that fish are, however, since they cannot take oxygen from the water, but must come to the surface to breathe.

Among the arboreal mammals are the monkeys, squirrels, and sloths. Some of the squirrels can even "fly" through the air for short distances, but as in the case of the flying dragon flight here is really only sailing through the air on

outstretched membranes. The bats, however, possess wings and are as much air inhabitants as the birds.

A few species, like the mole, pass almost their entire existence underground, and the ground squirrels, woodchucks, prairie dogs, and similar species live part of the time in burrows.

Protection. — Mammals, like birds, are warm-blooded animals and must be protected not only from their natural enemies and from the ordinary hard knocks of life, but also from weather conditions, such as extreme cold, which would not injure such cold-blooded creatures as the frog and turtle. Heat is kept in the body in various ways. Mammals that live in cold water, like the whale, possess a very thick layer of fat, the

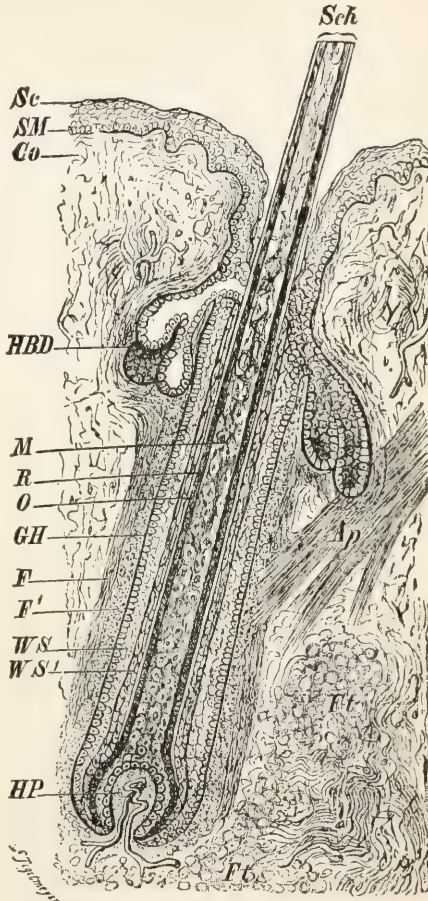

FIG. 271. — Longitudinal section through a hair in its follicle.

Ap, muscle; **Co**, dermis; **F**,**F'**, fibrous layers of follicle; **Ft**, fat; **GH**, membrane; **HBD**, sebaceous gland; **HP**, hair papilla; **M**, pith; **O**, cuticle; **R**, cortical layer; **Sc**, horny layer of epidermis; **Sch**, hair shaft; **SM**, epidermis; **WS**, **WS'**, layers of root-sheath. (From Wiedersheim.)

blubber, just beneath the skin, which prevents the escape of the body heat. The more usual method of protection from the cold is a thick covering of hair.

Hair. — All mammals possess hairs and may be distinguished from all other animals by these peculiar structures. The hairs project out from pits in the skin, called hair follicles (Fig. 271). The hair shaft (*Sch*) broadens at the base, extending around a highly vascular papilla (*HP*) at the bottom of the pit. When hairs are shed, new hairs usually arise to take their place. Secretions from the sabaceous glands (*HBD*) keep the hairs glossy.

The two main types of hairs are (1) contour hairs which are long and strong and (2) woolly hairs which are shorter and constitute the under fur. In some animals the woolly hairs have a rough surface, as in the sheep, which causes them to cohere and gives them their felting quality. Certain of the stronger hairs may be moved by muscular fibers (Fig. 271, *Ap*), which are responsible for the erection of spines or the gristling of the other hairs.

The air spaces between the hairs prevent the escape of heat since air is a bad conductor of heat. Besides protecting the body from loss of heat the hairy covering also prevents to a large extent injury due to blows. Human beings are almost entirely covered by hair, except on the soles of the feet and palms of the hands. This covering is of practically no service except the thick growth on the head.

Color. — As a rule mammals are not very highly colored, but many of them are characterized by stripes, as in the zebra and tiger, or spots, as in the leopard. The dull colors of mammals and the stripes or spots are all supposed to aid in concealing the animals amid their surrounding and thus to protect them from their enemies. Animals like the Arctic fox that live in the colder regions of the earth change color in the winter, becoming white. This change is of advantage, since it renders them inconspicuous against the background of snow.

Claws, Nails, Hoofs, and Horns. — Mammals protect themselves from their enemies when in actual combat by means of their teeth, claws, nails, horns, and hoofs. The claws, nails, and hoofs are all modifications of the horny covering on the upper surface at the end of the digits (Fig. 272). The foot may rest partially or entirely on these structures, as in the case of the

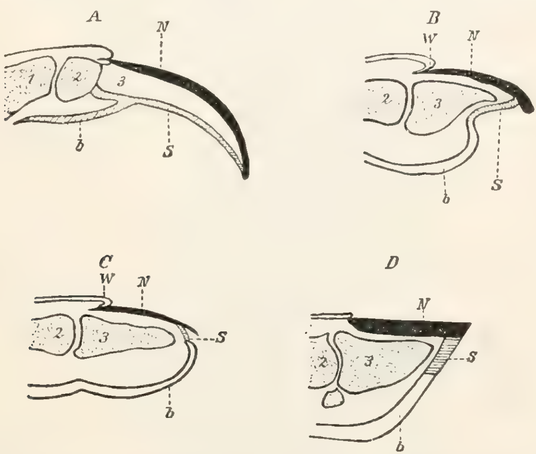

FIG. 272. — Diagrammatic longitudinal sections through the distal ends of the digits of mammals.

A, spiny anteater; **B**, dog; **C**, man; **D**, horse.
1–3, phalanges; **b**, torus; **N**, nail plate; **S**, sole horn; **W**, bed of claw or nail. (From Wiedersheim.)

horse, but, as a rule, it is partly supported on the pads just beneath them. The horns of the rhinoceros and the horn sheaths of cattle are, like claws and hoofs, formed from the outer layer of the skin, the epidermis, but in many other animals the horns are of bone, and even in cattle the central core of the horn is bone. Some animals, like the deer and prong-horned antelope, shed their horns annually and a new set gradually grows to take their place; others, like cattle and sheep, normally keep one pair of horns throughout life. In many cases only the male individuals of a species possess horns.

Locomotion. — The habitat of an animal determines to a large extent its method of locomotion. Whales swim about easily in the water, but are helpless on land. Seals and walruses are likewise excellent swimmers, but their flippers and heavy bodies make locomotion on land very slow and awkward. Most of the

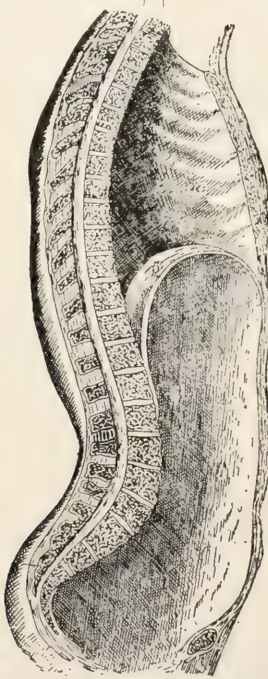

FIG. 273. — Longitudinal section through the trunk of a human body (side view). (From Peabody and Hunt.)

mammals walk, run, or hop, but a few of them can sail through the air for short distances, and the bats can actually fly.

Internal Organs. — The body cavity in which the internal organs lie is in mammals divided into two parts by a transverse muscular partition called the diaphragm. The anterior portion

(upper portion in man) contains the heart and lungs. The posterior cavity is filled with the abdominal viscera (Fig. 273).

Digestion. — The digestive system is similar to that of other vertebrates in general structure, consisting of an alimentary

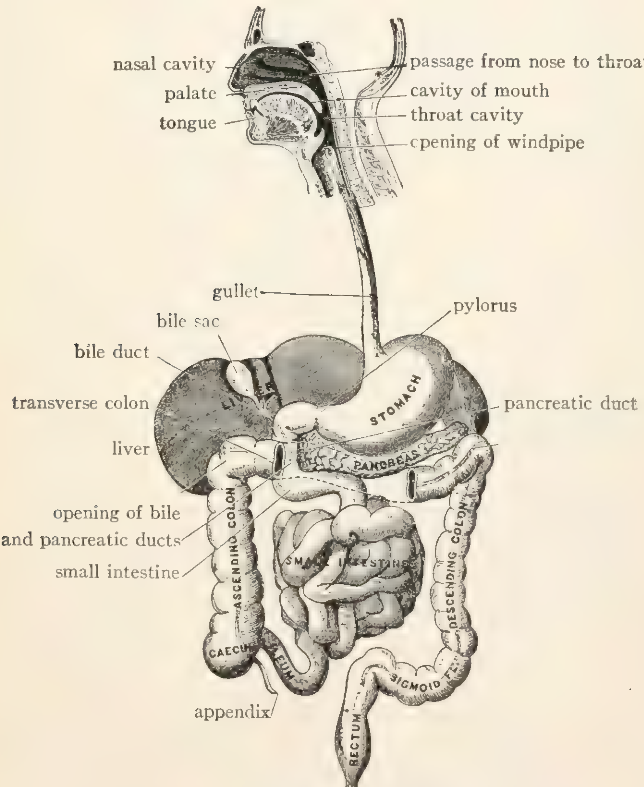

FIG. 274. — Parts of the alimentary canal of man. (From Peabody and Hunt.)

canal and the glands connected with it (Fig. 274). The alimentary canal begins with the mouth cavity in which are the tongue and teeth, then follow in succession the œsophagus, stomach, small intestine, large intestine, and rectum. The

principal glands are the salivary glands connected with the mouth, and the liver and pancreas connected with the small intestine. These glands secrete digestive juices, and other smaller glands in the walls of the stomach and intestine share in this duty.

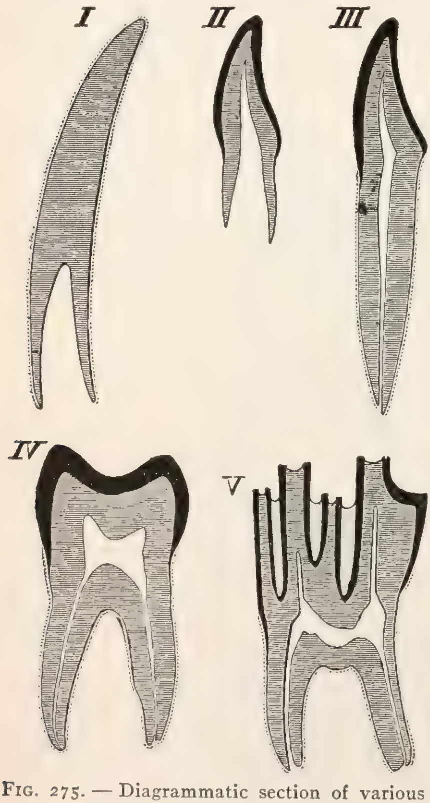

FIG. 275. — Diagrammatic section of various forms of teeth.

I, incisor or tusk of elephant with pulp cavity open at base; **II**, human incisor, during development, with pulp cavity open at base; **III**, completely formed human incisor, opening of pulp cavity small; **IV**, human molar with broad crown and two roots; **V**, molar of ox, enamel deeply folded and depressions filled with cement.

Enamel, black; pulp, white; dentine, horizontal lines; cement, dots. (From Flower and Lydekker.)

Teeth. — The teeth of mammals are among their most interesting possessions since they vary so much in the different species and indicate what kind of food is eaten by their owners. Most mammals are provided with teeth, but the whalebone whales, the egg-laying species, and anteaters are without them in the adult stage, and in some forms they have never been found, even in the embryo.

The teeth are embedded in sockets in the bone, and arise from the mucous membrane of the mouth. The principal forms of teeth and the relations of the materials composing them are shown in Fig-

ure 275. The enamel (in black) is the outer hard substance; the dentine (horizontal lines) constitutes the largest portion of the tooth; and the cement (dotted) usually covers the part of the tooth embedded in the tissues of the jaw. The central pulp cavity of the tooth contains nerves, blood vessels, and connective tissue. Teeth have an open pulp cavity during growth (Fig. 275, II), which in some cases continues throughout life (Fig. 275, I).

The teeth of fishes, reptiles, and amphibians are usually all similar, but in mammals there are commonly four kinds in each jaw: (1) the chisel-shaped incisors in front (Fig. 276, *i 2*), (2) the conical canines (*c*), (3) the anterior grinding teeth or premolars (*pm 1 – pm 4*), and (4) the posterior grinding teeth or molars (*m 1*).

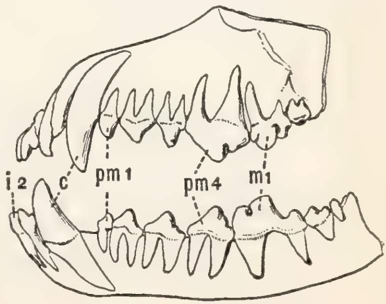

FIG. 276. — Teeth of dog.

i 2, second incisor; **c**, canine; **pm 1**, **pm 4**, first and fourth premolars; **m 1**, first molar. (From Shipley and MacBride.)

In most mammals the first set of teeth, known as the milk dentition, is pushed out by the permanent teeth, which last throughout the life of the animals. The milk molars are followed by the premolars, but the permanent molars have no predecessors.

The relation of the form of the teeth to the food habits of the animal may be shown by the following examples. The dolphins have a large number of sharp, conical teeth adapted for capturing fish; the carnivorous animals, like the dog (Fig. 276), are provided with large canine teeth for capturing and killing their prey, small and almost useless incisors, and molars with sharp edges for cutting or crushing; herbivorous mammals, like the ox, possess broad incisors for biting off plants, no canines, and large grinding molars; gnawing mammals, like the rabbit, have incisors that grow throughout life, but are worn down by

gnawing, thereby maintaining a serviceable length and a keen cutting edge; insect-eating mammals, such as the shrew, seize insects with their projecting incisors and cut them into pieces with the pointed cusps on their premolars and molars; and man and other omnivorous animals are provided with teeth fitted for masticating both animal and vegetable matter.

Circulation. — The heart in mammals is more highly developed than in any other vertebrate. The ventricle is divided into two chambers that are perfectly distinct. The pure blood (in the pulmonary veins), passing from the lungs, enters the left auricle, passes thence into the left ventricle, whence it is driven (through the aorta) over the body. After having traversed all the parts of the body and become richly loaded with carbonic acid gas, it returns to the heart, entering the right auricle, and passing thence into the right ventricle, whence it is pumped through the pulmonary arteries back into the lungs. Thus by the division of the heart into two halves the arterial is completely separated from the venous blood.

The blood corpuscles are unlike those of the lower vertebrates, being smaller, round instead of oval, biconcave, and without nuclei. The lymphatic system is of considerable importance in mammals. The fluid portion of the blood, which, because of the blood pressure, escapes through the walls of the capillaries into the spaces among the tissues, is collected into lymph vessels. These vessels pass through so-called lymph glands and finally empty into the large veins in the neck. The lymphatics which collect nutriment from the intestine are called lacteals.

Respiration. — Mammals breathe air by means of lungs. The trachea or windpipe is held open by incomplete rings of cartilage; and the larynx, or voice box, is supported by a number of cartilages, and across its cavity extend two elastic folds called the vocal cords.

The lungs are conical in shape, and lie freely in the thoracic cavity. Air is drawn into them by the enlargement of the

cavity. This is accomplished both by pulling the ribs forward and then separating them and by means of the diaphragm. The diaphragm is normally arched forward (up in man, Fig. 273), and when it contracts, it flattens, thus enlarging the thoracic cavity. The increased size of this cavity results in the expansion of the lungs, because of the air pressure within them, and the inspiration of air through the nostrils. Air is pumped out of the lungs (expiration) by the contraction of the elastic lung vesicles and of the thoracic wall and diaphragm.

Excretion. — Waste products are cast out of the body by the kidneys and skin. The kidneys are the principal excretory

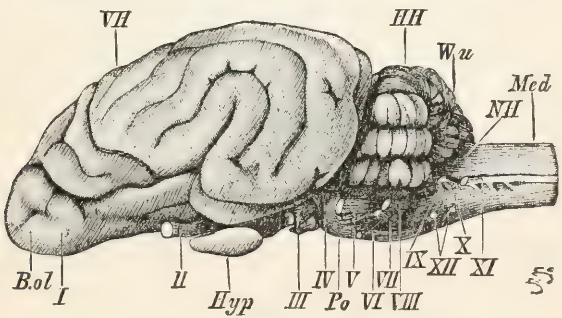

FIG. 277. — Brain of dog. Side view.

I–XII, cranial nerves; **B.ol**, olfactory lobe; **HH**, cerebellum; **Hyp**, hypophysis; **Med**, spinal cord; **NH**, medulla oblongata; **Po**, pons Varolii; **VH**, cerebrum; **Wu**, cerebellum. (From Wiedersheim.)

organs. The urine which they extract from the blood is carried by two slender tubes, the ureters, into a thin-walled, muscular sac, the urinary bladder. At intervals the walls of the bladder contract, forcing the urine out of the body through the urinogenital aperture. In the skin of man are numerous sweat glands and sebaceous glands which aid the kidneys in excreting waste material.

Nervous System. — The nervous system is very highly developed in mammals. The brain (Fig. 277) differs from that of the lower vertebrates in the large size of the cerebral hemi-

spheres and cerebellum. The cerebral hemispheres are marked by depressions which divide the surface into lobes or convolutions not present in birds. In man the cerebrum constitutes nine-tenths of the bulk of the brain, and the convolutions are very deep.

Sense Organs. — THE EYE (Fig. 278). — The eyes lie within protective cavities, the orbits. In the center of each eye there

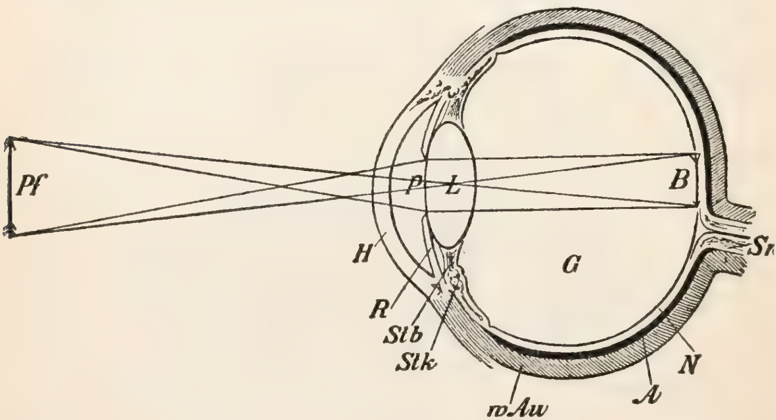

FIG. 278. — Section through human eye.

A, choroid; **B**, image on retina; **G**, vitreous body; **H**, cornea; **L**, lens; **N**, retina; **p**, pupil; **Pf**, object; **R**, iris; **Sn**, optic nerve; **Stb**, **Stk**, ciliary muscle and ciliary fold; **wAu**, sclerotic. (From Schmeil.)

is an aperture for the entrance of light, forming the pupil. This aperture contracts in a bright light and dilates in a faint light. Directly behind the pupil is a lens-shaped body, the crystalline lens. The space in front is filled with a watery fluid, the aqueous humor; that behind the lens with a gelatinous substance, the vitreous body. The eye is constructed on the same plan as the camera of the photographer. On the retina, as on the sensitive plate of the camera, there is formed an inverted and diminished image of the external world, and the retina, being composed of nerve terminations sensitive to light,

transmits the image to the brain by way of the optic nerve. The eyelids and eyelashes protect the eyes from injury.

THE EAR. — The ear (Fig. 279) is the organ of hearing. In most mammals external, funnel-shaped projections catch the sound waves. These waves enter the ear passage and induce

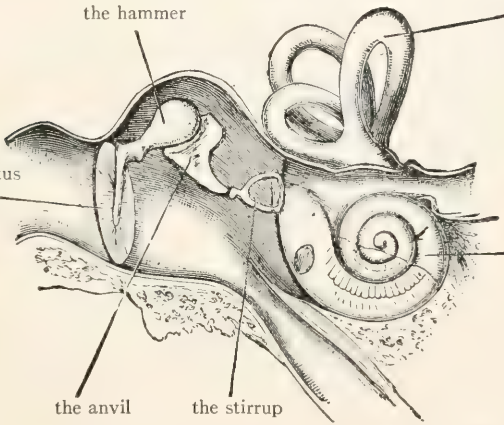

FIG. 279. — Middle and inner human ear. (From Peabody and Hunt.)

vibrations in the tympanic membrane, which are transmitted to the small bones of the ear lying in the cavity of the tympanum. The end of the innermost of the small ear bones (stapes) is applied to a fine membrane of the inner ear, or labyrinth, which lies in a corresponding bony cavity. This membrane in its turn receives the vibrations and transmits them to a fluid contained in the labyrinth. Thence the vibrations reach the terminations of the auditory nerve, and are conveyed to the brain, where they enter into the consciousness in the form of tones or noises.

TOUCH. — Sensations of touch are conveyed by the whole skin; as special organs of touch we may enumerate the tips of the fingers, the lips with the special bristles, the wing membrane in bats, as well as the tongue.

Smell. — The nose is the organ of smell. Its cavities are lined with a membrane that is supplied with nerve endings from the olfactory nerve. These are stimulated by substances in the air that enter the nose during inspiration.

Taste. — Organs of taste are present on the tongue and enable mammals to determine the nature of the food they eat.

The Skeleton. — The skeleton of mammals (Fig. 280) consists almost entirely of bone. It serves the same purposes as does that of the frog (p. 254), but of course it differs somewhat in details of structure. The bones are similar in number and position in all mammals, but they are modified according to the habits of the species. A comparison of the bones in various kinds of mammals and in other vertebrates makes a very interesting study.

Reproduction. — Mammals are separated into male and female individuals. The essential organs of the male are two testes in which the spermatozoa arise and the ducts which carry the spermatozoa to the outside. The female organs in which the eggs are produced are the two ovaries. Connected with these ovaries is an egg duct, the oviduct, into which the fully grown egg passes. Here it is fertilized by a spermatozoon. In most cases the eggs develop within the egg tubes of the mother. The young embryo becomes connected with the wall of the egg tube by a strand of membranes and blood vessels called the placenta. Through the placenta, nourishment from the blood of the mother is carried to the growing young. The interval between fertilization and the birth of the young which develop from the fertilized egg is known as the period of gestation. This period varies in different species; in the rabbit it is thirty days. From one to eight or ten young may be produced at a birth, and, in the case of rabbits, several litters may be born during the year.

Animal Tracks. — The study of mammals in their native haunts is rather difficult since most of them are so badly persecuted by man that they conceal themselves as soon as they become aware of the presence of human beings. We have already

noted (p. 349) that the study of birds is often interfered with by the leaves of trees which hide them. As a remedy it was

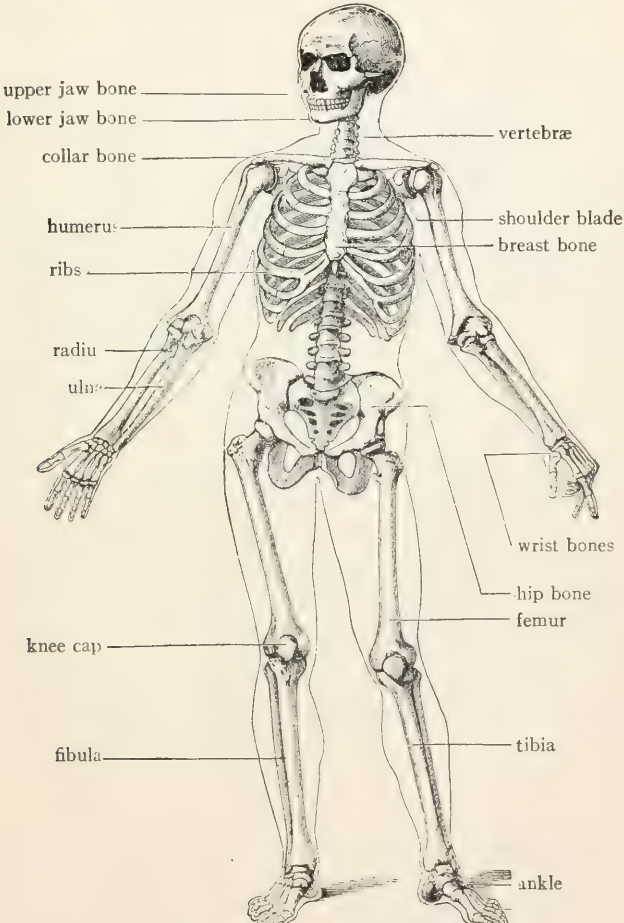

FIG. 280. — Skeleton of man. (From Peabody and Hunt.)

suggested that the call notes and songs of birds should be learned, since we could thus recognize the birds, even if we could not see

them. There is also a remedy in the case of mammals, and that is the study of animal tracks.

By an animal track is meant the footprint of an animal. When these footprints continue for some distance, they constitute a trail. Broken twigs and other signs are also of service in deciding what kind of animal was present and what it was doing. The character of the track depends somewhat on the way the animal walks. The bears and man, for example, walk upon the entire surface of the digits; they are called plantigrade. Cats and dogs rest only upon the outer parts of the digits (digitigrade), and the hoofed mammals such as the horse are supported on the ends of the digits (unguligrade).

The snow records the movements of animals very clearly, and consequently winter is the best time to study animal tracks (Fig. 281). Hard, dry snow, like a daily newspaper, is only a temporary medium, but tracks made in loose, wet snow may last for weeks or months. Wet sand, clay, or mud are also good recorders of animal tracks, but they can be found, as a rule, only near bodies of water.

To determine the kind of animal one is tracking it is necessary to know something of the habits of the animals, the structure and size of their feet, and their methods of locomotion. Thus the tracks of the mink, least weasel, and wolverine are shaped alike, but that of the weasel is only an inch long whereas that of the wolverine is five inches long, and the track of the mink may end in a hole in the ice. The direction in which an animal was moving may be determined by the claws.

Tracks frequently indicate emotions such as fear, dislike, or anger. Fear or caution are most often expressed. For example, a rabbit came through a forest and was forced to cross a frozen creek before it could reach a swamp it wished to enter. The distance between its tracks as it neared the creek decreased from over three to less than two feet. It finally landed backward at the edge of the forest, facing its track to see if it was being pursued. Here it stayed long enough to melt the snow under its

paws. Then it bounded across the creek, covering about five feet at each leap. Again it landed facing the track it had made. Being satisfied that it had escaped observation, it entered the swamp at a leisurely pace.

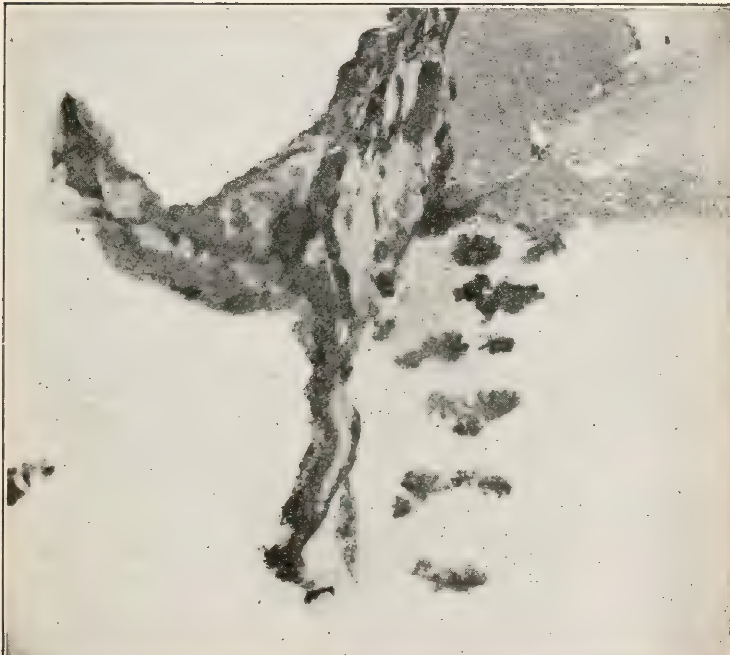

FIG. 281. — Tracks in the snow showing where a musk rat has come from and returned to the water. (From Dugmore.)

Hibernation. — The problem of maintaining life during the winter is solved by most birds by migrating. Mammals, on the other hand, usually remain active, like the rabbit, or hibernate. During hibernation the temperature of the body decreases and the animal falls into a profound torpor. A cold-blooded animal, like the frog, can be almost entirely frozen without being injured, but warm-blooded animals must protect themselves from the

cold. They therefore seek a sheltered spot, such as a burrow in the ground, in which to spend the winter. Furthermore, at this time the fur of mammals is very thick and consequently helps to retain the body heat.

The temperature of the body of hibernating animals becomes considerably lower than normal; for example, a ground squirrel which hibernated in a temperature of 35.6° F. had a body temperature exactly the same. Respiration almost ceases; the heart beats very slowly; and no food is taken into the body, but the fat masses stored up in the autumn are consumed, and the animal awakens in the spring in an emaciated condition.

The woodchuck is the most profound sleeper of our common mammals. It feeds on red clover in the autumn, goes into its burrow about October 1, and does not come out until April 1. The bear does not sleep so profoundly, for if there is plenty of food and the temperature is mild, he will not hibernate at all. When the bear does hibernate, he scoops out a den under a log or among the roots of a hollow tree. The raccoon and gray squirrel sleep during the severest part of the winter; the skunk spends January and February in his hole; the chipmunk wakes up occasionally to feed; and the red squirrel is abroad practically all winter. Many other mammals hibernate for a greater or less period of time.

Migration. — Comparatively few mammals migrate; this may be due in part to their inadequate means of locomotion. Among those that do migrate are the fur seal, reindeer, caribou, bison, bat, and lemming. The *fur seals* in American waters breed on the Pribilof Islands in Bering Sea, where they remain from about May 1 to September 15. They then put out to sea, spending the winter months making a circuit of about six thousand miles.

The *reindeer* of Spitzbergen migrate regularly to the central portion of the island in summer and back to the seacoast in the autumn, where they feed upon seaweed. The bisons used to range over a large part of North America, making regular spring

and fall migrations. They covered an area of about thirty-six hundred miles from north to south, and two thousand miles from east to west. Similar migrations are made by the caribou in Newfoundland (Fig. 282).

FIG. 282. — The Newfoundland caribou in migration. (From Dugmore.)

The *lemmings* of Scandinavia (Fig. 283) are celebrated for their curious migrations. They are small, gnawing animals about three inches in length. " At intervals, averaging about a dozen years apart, lemmings suddenly appear in cultivated districts in central Norway and Sweden, where ordinarily none live, and in a year or two multiply into hordes which go traveling straight

west toward the Atlantic, or east toward the Gulf of Bothnia, as the case may be, regardless of how the valleys trend, climbing a mountain instead of going around it, and, undeterred by any river or lake, keep persistently onward until finally some survivors reach the sea, into which they plunge and perish." They are said to march in "parallel lines three feet apart" and "gnaw through hay and corn stacks rather than go around."

FIG. 283. — The Norwegian lemming. (From Ingersoll.)

Geographical Distribution. — The various species of mammals and other animals are rather definitely restricted to certain regions on the earth's surface. The earth has an area of about two hundred million square miles, five-eighths of which is covered by the sea. This vast territory is not uniform, but presents a great number of sets of conditions. The principal habitats are the solid earth, the liquids upon the earth, and the atmosphere. The facts of geographical distribution have led to the formulation of the three following laws: (1) the law of definite habitats, (2) the law of dispersion, and (3) the law of barriers and highways.

THE LAW OF DEFINITE HABITATS. — Among the most important physical factors that determine the habitat of an animal are temperature, water, light, and food. The continent of North America has been divided by scientists into definite regions, according to the sum total of the *temperature* during the season of growth; and regions of a certain temperature, though widely separated, are liable to support similar kinds of animals. Winter

is met by northern animals in one of four ways: (1) by dying, *e.g.* adult butterflies, (2) migrating, *e.g.* birds, (3) hibernating, *e.g.* bears, (4) remaining active, *e.g.* rabbits. Animals living in tropical regions pass the summer in many cases in a torpid condition, and are said to be æstivating.

A certain amount of *water* is necessary for life, as the bodies of animals are made up of from 55 to 95 per cent water. Animals living in dry climates have thick skins, and thus evaporation is prevented.

Light plays a leading rôle in the lives of animals; many species require it, but others shun it as much as possible, principally in order to escape their enemies.

And finally, *food* conditions are most effective, since carnivorous animals, *e.g.* lions, must live where they may obtain flesh; herbivorous animals, *e.g.* deer, must live where suitable vegetation abounds; and omnivorous animals, *e.g.* man, where both flesh and vegetation of certain sorts exist.

The Law of Dispersion. — Animals tend to migrate from the region of their birth. It is supposed that every animal produces a greater number of offspring than can be supported in its particular habitat, and since parents and offspring cannot occupy the same area, some individuals must either migrate or die.

The Law of Barriers and Highways. — Animals are confined to certain habitats by *barriers* and are prevented from entering a new region by mountains or lakes, by lack of food, and by the interference of other animals. Common barriers are mountains, bodies of water, open country for forest animals, and forests for prairie-inhabiting species. The reverse of a barrier is a *highway*. Apparently there are routes of migration which are especially favored.

Cosmopolitan Groups of Animals. — Some species of animals have wide ranges, *e.g.* some are found inhabiting practically every large land area on the earth's surface. This is true of many birds and of the bats among the mammals.

2 E

Restricted Groups of Animals. — In a number of cases certain species are restricted to very limited areas. The mountain goat is found only in the higher Rocky and Cascade mountains of Alaska. Islands are famous for the presence of restricted species. Darwin's descriptions of the animals he found in the Galapagos Islands read like fairy tales.

Discontinuous Distribution. — Whenever a species occurs in two widely separated regions, it is safe to conclude that the distribution must once have been continuous. Examples of discontinuously distributed animals are rare. Tapirs inhabit tropical America and nowhere else except the Malay Archipelago.

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CHAPTER XXXIX

THE ORDERS OF MAMMALS

THE seventy-five hundred species of living mammals may be grouped into a number of orders. Some orders contain more common or more important species than others and a few are represented only by a few little-known animals. The groups described in the following paragraphs are for the most part illustrated by species that occur in this country.

Egg-laying Mammals. — These primitive mammals are confined to Australia, New Guinea, and Tasmania. Their most conspicuous peculiarity is their egg-laying habit, since they are the only mammals that reproduce in this way. The young before hatching live on the yolk contained in the egg. After hatching they are for a time nourished by milk from the mammary glands.

FIG. 284. — The duckbill. (From Shipley and MacBride.)

The *duckbill* (Fig. 284) is adapted for life in the water. It possesses webbed feet, a thick covering of waterproof fur like that of a beaver, and a duck-like bill with which it probes in the mud under water for worms and insects. During the daytime the duckbill sleeps in

a grass-lined, underground chamber at the end of a long burrow in the bank, the entrance of which is under water. In this chamber one or two eggs are laid and the young reared.

Pouched Mammals. — These mammals occur mainly in Australia and neighboring islands, but a few are natives of America. Their method of reproduction is peculiar. The eggs are not laid,

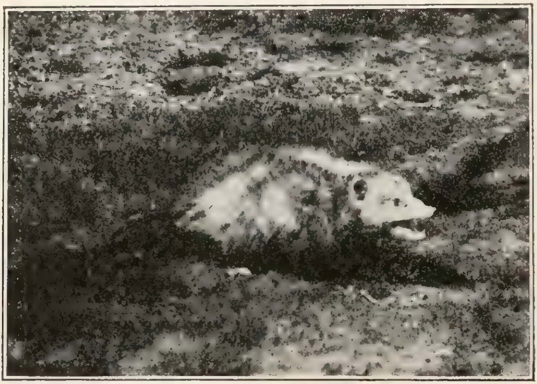

FIG. 285. — Opossum. (Photo. by Hegner.)

but hatch within the mother's body and the young are born in an immature condition. The mother transfers them with her lips to a pouch on the abdomen, where they are fed upon milk from the mammary glands.

The *opossum* (Fig. 285) occurs in the Southern and Middle States. It sleeps during the day, usually in a hollow tree or stump, but is active at night, seeking insects, eggs, young birds and mammals, berries, nuts, etc., which constitute its food. When disturbed, the opossum frequently feigns death or "plays possum." Two or three litters of from six to fourteen young each are produced per year. The young remain with the mother for about two months, at first in the pouch and later often riding about on her back. Opossums are used as food in the south, and when properly roasted, are excellent.

The *kangaroos* inhabit the Australian region. They range in size from four to five feet in height to that of a small rabbit. The fore limbs are very small and are used principally for grasping, whereas the hind limbs and tail are strongly developed, enabling the animals to move about rapidly by a series of leaps. The natives of Australia hunt them both for sport and for food, In some localities they are injurious, since they eat the grass necessary for feeding the cattle and sheep.

Insectivores. — These are small mammals that are nocturnal in habit and feed principally on insects which they seize with their projecting front teeth and cut into pieces with the sharp-pointed cusps on their hind teeth. Most of them are terrestrial,

FIG. 286. — Garden mole. (Photo. by Brownell.)

but a number are subterrestrial (*i.e.* burrow). The moles are stout, with short fore legs, fore feet adapted for digging, rudimentary eyes, and without external ears. The *common mole* (Fig. 286) ranges from southern Canada to Florida. It burrows just beneath the surface of the ground, and is of considerable benefit because of the insects it destroys, though its upheaved tunnels soon disfigure a lawn. The rate of progress underground is astonishing. One will tunnel a foot in three minutes, and a single specimen under normal conditions is known to have made a runway sixty-eight feet long in a period of twenty-five hours.

FIG. 287. A bat in a sleeping position. (Photo. by Brownell.)

Bats. — The bats are easily distinguished from other mammals by the modification of their fore limbs for flight. The fore arm and fingers are elongated and connected with each other and with the hind feet, and usually the tail, by a thin leathery membrane. Because of their remarkable powers of locomotion bats are very widely distributed, occurring on small islands devoid of other mammals. Most of them are small and chiefly nocturnal. During the day they go into retirement and hang head downward suspended by the claws of one or both legs (Fig. 287). At night bats fly about actively in search of insects. Some of them live on fruit, and a few suck the blood of other mammals.

FIG. 288. — A flying "fox." (U. S. Dept. of Agric.)

The largest of the bats are the flying "foxes," one species of which has a wing expanse of five feet and a body one foot in length (Fig. 288). The fruit bats feed on fruit, especially figs and guava, and move about in companies. The brown bat is a common species inhabiting the United States. The

true vampire bats inhabit South America. They live on the blood of horses, cattle, and other warm-blooded animals, and sometimes attack sleeping human beings. Their front teeth, which are very sharp, cut the skin, and the oozing blood is lapped up.

FIG. 289. — Red fox. (From Stone and Cram. Copyright by Doubleday, Page and Co.)

Flesh-eating Mammals. — The teeth of carnivorous animals are adapted for eating meat. The front teeth, or incisors (Fig. 276), are small and of little use; the canines (*c*), or eyeteeth, are very large and pointed, enabling the animal to capture and kill its prey; the premolars (*pm 1*, *pm 4*) and the first molar in the lower jaw (*m 1*) have sharp-cutting edges; the other molars

are broad, crushing teeth; the fourth premolar of the upper jaw (*pm 4*) and the first molar of the lower jaw (*m 1*) bite on one another like a pair of scissors.

TERRESTRIAL CARNIVORES. — The *dog family* is represented in North America by the wolves, coyotes, and foxes. The *red fox* (Fig. 289) is persistently hunted by the poultry raiser because of its fondness for chickens, but the benefits derived from the

FIG. 290. — Striped hyæna of Africa. (From Beddard.)

destruction of field mice, rabbits, ground squirrels, woodchucks, and insects, which constitute the larger part of a fox's food, probably more than repay the loss of a few fowls. Foxes seek their food most actively in the morning and evening twilight. They mate in February and March, and give birth on the average to five young in April or May.

The *gray wolf* of the Great Plains and the Rocky Mountains is over four feet in length and very powerful. Wolves hunt in packs, and are able to capture deer and other large animals. They destroy great numbers of calves, colts, and sheep, and are shot, trapped, or poisoned whenever possible. Many states pay

a high bounty for wolf scalps. The young, usually five in number, are born early in May. The hyænas (Fig. 290) which live in Africa and Asia are closely related to the "dogs" of this country.

The best-known members of the *bear family* in North America are the polar bear, black bear, grizzly bear, and the large Alaska brown bear. The polar bear frequents the coasts of the Arctic Ocean, feeding principally upon seals, walruses, and fish. The black, brown, or cinnamon bear is a smaller species abundant throughout the forested regions of North America, where not exterminated. It is omnivorous, being especially fond of fish, blueberries, and honey. The grizzly bear of the Rocky Mountains (Fig. 291) is now rare except in the Yellowstone Park and certain other limited localities.

Fig. 291. — Grizzly bear. (From Ingersoll.)

The *marten family* contains a large number of small fur-bearing animals. The otter, mink, weasel, marten, wolverine, skunk, and badger are well known North American species. The *otter* (Fig. 292) is over three feet in length. It makes its home in a burrow in the bank of a lake or stream and is very fond of water, being adapted for swimming by webbed feet and a flattened tail. Fish constitute its chief food. Otter fur is very valuable, but it cannot be obtained now except in certain parts of Alaska, where the natives capture the sea otter, a single skin of which is worth in some cases one thousand dollars.

Fig. 292. — Otter. (Photo. by Beebe from Stone and Cram. Copyright by Doubleday, Page and Co.)

The *mink*, like the otter, is fond of water. Its food consists of birds, small mammals, and fish. The *weasel* (Fig. 293) is much smaller but very bloodthirsty, often killing a great many more

FIG. 293. — Weasel. (Photo. by Carlin from Stone and Cram. Copyright by Doubleday, Page and Co.)

birds and small mammals than it can eat. The *skunk* is notorious because of the powerful odor of the secretion which it can eject from a pair of scent glands at the base of the tail. It feeds upon poultry, but pays for its board by killing grubs and other noxious insects. The *badger* inhabits western North America, lives in a burrow in the ground, and feeds on small mammals. The *wolverine* (Fig. 294) occurs in the northern

United States; it is a fierce, greedy animal and a great thief, stealing bait from traps, and even the traps themselves.

Fig. 294. — Wolverine. (Photo. by Hegner.)

The *cat family* includes the cat, puma, leopard, lion, tiger, lynx, and cheetah. The principal species inhabiting North America are the wildcat, Canada lynx, puma, and jaguar. The wildcat (Fig. 295), also called bay lynx, bob cat, or catamount, is a stubtailed animal about three feet in length, and weighs up to eighteen pounds. It was formerly common, but is now restricted to the forests of thinly settled localities. Its food consists of rabbits, poultry, and other birds and mammals. The *Canada lynx*, or "loup cervier," is slightly larger than the wildcat, and can be recognized by a tuft of stiff, black hairs projecting upward from each ear. It

Fig. 295. — Wildcat. (Photo. by Hegner.)

occurs in the northern United States and in Canada. The *puma*, cougar, mountain lion, or panther, reaches a length of over eight feet, of which the tail constitutes about three feet. Pumas make their homes in rocky caverns or in forests. They prey upon many kinds of animals, frequently causing much damage by killing young colts; but they do not attack man unless cornered. The *jaguar* is the largest American cat, but only occasionally enters the southern United States from Mexico, where it is common. It is afraid of man, but is a dangerous enemy of deer, horses, cattle, and other animals.

The largest living cat is the *tiger*, whose body reaches a length of ten feet; it is most abundant in southern Asia. The *lion* is found in Africa and certain parts of Asia; it is slightly smaller than the tiger. The *cheetah*, or hunting leopard, occurs in parts of Asia and Africa. In India it is trained to capture game.

AQUATIC CARNIVORES. — The aquatic carnivores are greatly modified for life in the water. The hands and feet are fully webbed, and serve as swimming organs, and the body has acquired a fishlike form suitable for progress through the water.

The *sea lion family* includes the sealions and fur seals. The *fur seal* breeds on the Pribilof Islands in Bering Sea, but at other times occurs along the coast of California. Fur seals are polygamous, and a single old male maintains control over from six to thirty females. One young is produced each year. The three-year-old males, called "bachelors," are the ones killed for their fur. The *California sea lion* is the member of this family most often seen in captivity. Squids, shellfish, and crabs are its principal articles of food. Its fur is short, coarse, and valueless.

The *walrus family* contains the Atlantic walrus and the Pacific walrus (Fig. 296). An adult male walrus is ten or twelve feet long and weighs almost a ton. The canine teeth of the upper jaw are very long, and are used to dig up mollusks and crustaceans from the muddy bottoms, and to climb up on the blocks of ice in the Arctic seas, where it lives. Walruses have been almost exterminated for their ivory, skins, and oil.

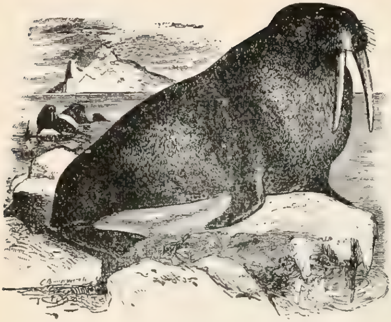

FIG. 296. — The walrus. (From Flower and Lydekker.)

The *seal family* contains a number of species, among them the harbor seal, which inhabits the North Atlantic.

Gnawing Animals. — The rodents are characterized by their long, chisel-shaped incisor teeth which are adapted for gnawing, and the absence of canines, leaving a gap between the incisors and premolars. They are all small or of moderate size and constitute the largest order of mammals. The best-known North American families are the rabbits and hares, the squirrels, the beavers, the pocket-gophers, the rats, mice, etc., and the porcupines.

The *squirrel family* includes the woodchucks, prairie dogs, tree squirrels, chipmunks, ground squirrels, and flying squirrels. The common *tree squirrels* (Fig. 297) are the gray, fox and red squirrels; these are all excellent climbers, and be-

FIG. 297. — Fox squirrel. (Photo. by Lyndon.)

come quite tame if unmolested. With the probable exception of the red squirrel or chickaree they should be protected.

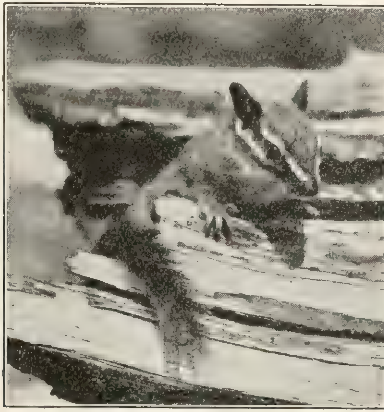

FIG. 298. — Chipmunk. (Photo. by Carlin.)

The *chipmunks* (Fig. 298), or rock squirrels, are small animals living usually on the ground among rocks. The *ground squirrels* are sometimes called gophers (Fig. 299). They are inhabitants

FIG. 299. — Striped gopher at entrance to hole in ground. (Photo. by Hegner.)

of open country and dig burrows in the ground. Their food consists of grain which they carry into their burrows in cheek pouches. The *prairie "dogs"* (Fig. 300) are burrowing rodents that live on our western plains in colonies of from forty to one thousand. They feed upon grass and other vegetation. The *woodchucks*, or ground "hogs," also live in burrows; but are usu-

Fig. 300. — Prairie dog at the entrance to its burrow. (Photo. by Brownell.)

ally not colonial, and prefer hillsides or pasture land for their homes. They feed on clover and other grass. The *flying squirrels* are delicate nocturnal rodents that spend the day asleep in a nest, usually in a cavity in a tree. They possess a thin fold of skin between the fore and hind limbs on either side, which, when spread out, acts like a parachute to sustain the animal in the air.

The *beaver family* contains the largest gnawing animals in North America. They are adapted for life in the water, possessing webbed hind feet and a broad, flat tail. The dams of wood, grass, and mud made by beavers are constructed for the purpose of forming ponds in which houses are built with underwater entrances (Fig. 301).

FIG. 301. — A beaver dam. (Photo. furnished by American Museum of Natural History.)

The members of the *pocket-gopher family* possess large cheek pouches, which open outside of the mouth, and strong fore feet provided with large claws suitable for digging (Fig. 302). Grain

and vegetables are carried in the pouches, and such quantities are destroyed as to make these rodents quite injurious to crops.

FIG. 302. — Pocket gopher. (Photo. by Hegner.)

The *rat family* includes the muskrats, lemmings, meadow mice, white-footed mice, and rats. About one-fourth of our mammals belong to this family. They are all small, the muskrat being one of the largest American species. The common house mouse, the Norway rat, and black rat have all been introduced into this country from the Old World.

The members of the *porcupine family* are characterized by the presence of spines, which normally lie back, but can be elevated by muscles in the skin (Fig. 303).

Toothless Mammals. — The toothless mammals are mainly inhabitants of South America. The *anteaters* possess a long, narrow snout, and are provided with long claws on the fore feet which are used to tear open ant hills. The tongue is long and slender and serves to capture the ants upon which the animals feed.

The *sloths* inhabit the tropical forests of Central and South America. They live in the tree tops, and hang to the underside of the branches by means of two or three long, curved claws. Their food consists of leaves and buds.

FIG. 303. — Porcupine. (Photo. by Brownell.)

The *armadillos* (Fig. 138) are curious mammals with an armor of bony plates. When disturbed, they roll up into a ball, in which condition they are not easily injured. The nine-banded armadillo lives in southern Texas.

Even-toed Hoofed Mammals. — This group contains the majority of the " game " animals, and includes the pigs, hippopotami, camels, giraffes, deer, antelopes, sheep, goats, cattle, etc.

These animals are characterized by the presence of an even number of hoofed toes.

The term *ruminant* has been given to the animals belonging to the camel, deer, giraffe, and ox families, since they ruminate or chew their cud. The food of these animals is swallowed without sufficient mastication; it is later regurgitated in small quantities and thoroughly chewed. This method of feeding enables "these comparatively defenseless animals to gather nutriment

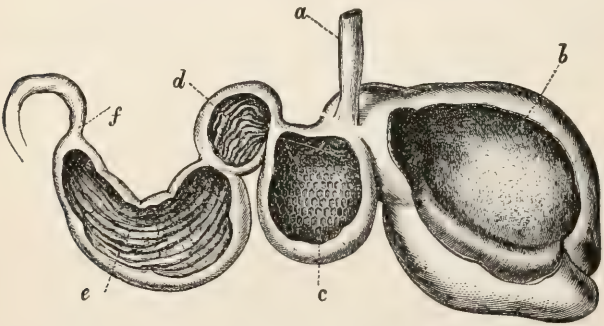

FIG. 304. — Stomach of a ruminant opened to show internal structure.

a, œsophagus; **b**, rumen; **c**, reticulum; **d**, psalterium; **e**, abomasum; **f**, duodenum. (From Flower and Lydekker.)

in a short time and then retreat to a safe place to prepare it for digestion." A typical ruminant possesses a stomach consisting of four chambers (Fig. 304). The food is first taken into the rumen chamber (*b*), where it is moistened and softened; it passes back into the mouth as "cuds" and is ground up by the molar teeth and mixed with saliva. When the cuds are swallowed, they are received by a second chamber (*c*), then pass into a third chamber (*d*), and finally into the fourth chamber (*e*).

The *deer* constitute the majority of the American hoofed mammals. Their horns or antlers are solid, and are shed annually. The best-known species are the wapiti or elk and Virginia deer, with round horns, and the caribou and moose, with flat horns.

The *moose* (Fig. 305) is the largest member of the family and possesses the most massive antlers. It inhabits the woods of the northern United States and British America, and feeds on bark, twigs, leaves, moss, and lichens.

FIG. 305. — Moose. (From Ingersoll.)

The *woodland caribou* (Fig. 282) lives in the forested parts of northern Maine and Montana and British America. The female caribou is our only female deer that bears antlers. The reindeer belongs to the same genus.

The *wapiti* or *elk* is the largest round-horned deer (Fig. 306). It is easily bred in confinement, and is common in zoological

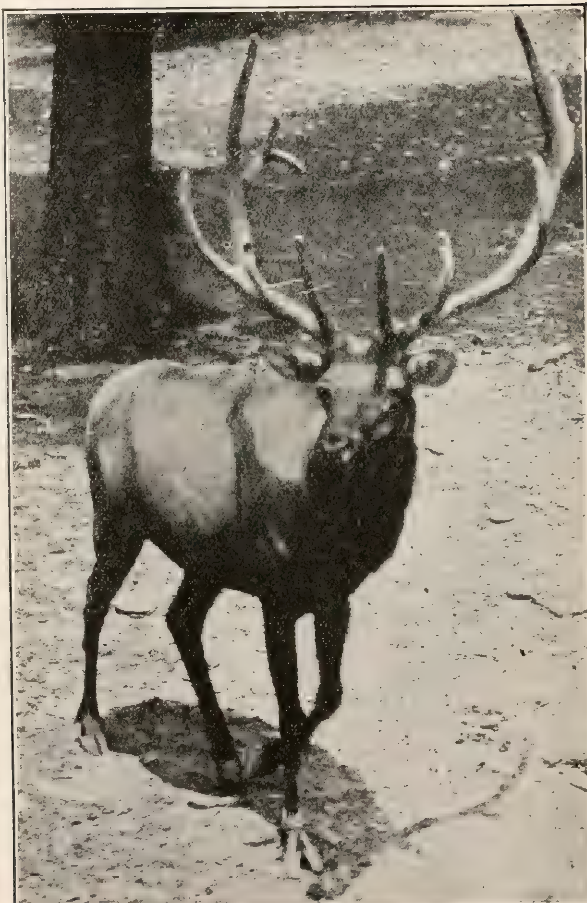

FIG. 306. — Elk or wapiti. (From U. S. Dept. of Agric.)

parks. The *Virginia* or *white-tailed deer* (Fig. 318) is the best known and most widely distributed of all our species. It is an inhabitant of forests.

The *pronghorn antelopes* are confined to the open country of

western North America. Their horns are hollow, branched, and shed annually.

The *ox family* contains the gnus, Rocky Mountain goats, sheep, goats, musk oxen, and bison. These are all ruminants, and both males and females usually possess unbranched, hollow horns, which fit over bony prominences on the skull and are not shed annually. The best-known American forms are the bison, musk ox, bighorn, and mountain goat.

FIG. 307. — Bison. (Photo. by Hegner.)

The *bison* (Fig. 307), up to the year 1870, ranged over a large part of the Great Plains and other portions of North America. It was persistently hunted, chiefly for its hide, until most of its kind had been killed. In 1903 it was estimated that about six hundred wild individuals and one thousand captive specimens still existed. The *musk ox* lives on the Arctic barrens of North America. It has a long, shaggy coat, and the male has a strong, musky smell. The Eskimos use it for many purposes. The *bighorn*, or *mountain sheep* (Fig. 308), is an inhabitant of the slopes of the Rocky and Sierra mountains above timber line. It seeks the more sheltered valleys in the winter. The *mountain*

FIG. 308. — Rocky mountain bighorn or mountain sheep. (From Ingersoll.)

goat occurs in the higher Rocky and Cascade mountains to Alaska. It is covered with long, white hair, has slender black horns, and is an expert climber.

Odd-toed Hoofed Mammals. — The horses, tapirs, and rhinoceroses which belong to this order are characterized by the presence of an odd number of hoofed toes. The horses, zebras, and asses of the horse family have but one functional toe on each foot, and two lateral splints. The *common horse*, of which over sixty domesticated races exist, is not now known in a wild state.

FIG. 309. — Zebra. (From Lydekker.)

The *Nubian ass* is probably the parent of the domestic donkey. The *zebras* (Fig. 309) are confined to Africa. The *tapirs* have four toes on the fore feet and three on the hind feet. The American members of this group have a long, prehensile nose. They feed on soft plants and are hunted for their flesh. The *rhinoceroses* are large, thick-skinned mammals with one or two epidermal horns on the nasal and frontal bones.

Elephants. — There are two species of elephants. The Asiatic elephant inhabits the jungles of India. The African elephant lives in tropical forests and is hunted for its tusks. Both species possess five digits on each foot; are covered by a thick, loose skin (whence they are called pachyderms) and a thin coat of hair; have a long, muscular proboscis with nasal openings at the tip; are provided with tusks which develop from the incisors; possess small eyes and tail and enormous ears; and are without canine teeth. The skull is massive, and the grinding teeth are very large.

Whales. — Whales are adapted to life in the water. They possess a very large head with elongated face and jaw bones; the fore limbs are modified as paddles; the tail is flattened horizontally and forms two lobes, the "flukes"; the eyes are small, and there is no external ear. The nostrils form a single opening, and

FIG. 310. — The sperm whale. (From Flower and Lydekker.)

the air, which is forced from it, condenses in the cold atmosphere, appearing like a spout of water. Beneath the skin is a thick layer of fat, or "blubber," which retains the body heat. The teeth are numerous and conical in shape.

TOOTHED WHALES. — The common *dolphin* is a toothed whale about seven feet in length; it occurs in the Mediterranean and in the warmer portions of the Atlantic. The *sperm whale* (Fig. 310) reaches a length of seventy-five feet, and is the largest toothed whale. Its oil, spermaceti, and blubber are sought by whalers. Cephalopods are its principal food.

WHALEBONE WHALES. — The whalebone whales possess teeth only in the embryo; they are provided in the adult stage with

numerous plates of whalebone, which are horny and frayed out at the end. In feeding, the whale takes large quantities of water into its mouth, and then forces it out through the sievelike whalebone, retaining any small organisms that may have entered with the water.

The *sulphur-bottom whale* (Fig 311) is the largest of all whales and the largest living animal, reaching a length of ninety-five feet, and a weight of about 294,000 pounds; it inhabits the

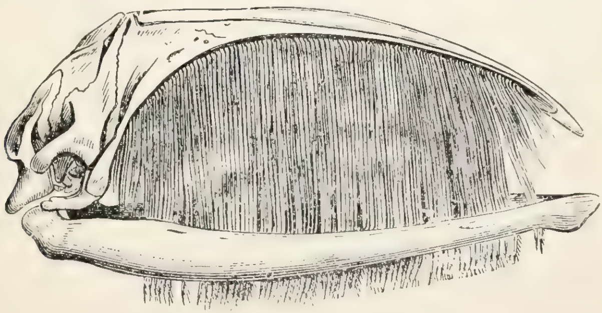

FIG. 311. — Skull of Greenland whale showing whalebone. (From Sedgwick.)

Pacific from California to Central America. The *Greenland whale*, or bowhead, occurs in polar seas and reaches a length of about sixty feet. One animal yields nearly three hundred barrels of oil and about three thousand pounds of the best whalebone.

Primates. — The primates inhabit chiefly the warm parts of the world. They are mostly arboreal in habit, and are able to climb about among the trees because the great toe and thumb are opposable to the digits, adapting the hands and feet for grasping. A few primates lead a solitary life, but most of them go about in companies. Fruits, seeds, insects, eggs, and birds are the principal articles of food. One young is usually produced at a birth, and it is cared for with great solicitude.

The *lemurs* (Fig. 312) are quadrupeds and small or moderate in size; they are covered with fur, and usually possess a long tail.

The *South American monkeys* are arboreal and of small or medium size (Fig. 313). The tail is usually long and prehensile, aiding in climbing. The space between the nostril openings is wide.

FIG. 312. — Ruffed lemur. (From Elliott. Courtesy American Museum of Natural History.)

The *Old World monkeys* are mostly quadrupedal (Fig. 314) and usually possess a long tail which is never prehensile; their nostrils are separated by a narrow space, and many of them have cheek pouches.

The *anthropoid apes* are the primates most nearly like man. The tail is absent and locomotion is often bipedal. There are

four genera in the family: (1) gibbons, (2) orang-utans, (3) gorillas, and (4) chimpanzees.

FIG. 313. — White throated capuchin, a South American monkey. (From Elliott. Courtesy American Museum of Natural History.)

The *gibbons* (Fig. 315) are arboreal, have a slender body and limbs, and reach a height of not over three feet.

The *orang-utans* (Fig. 316) are confined to Borneo and Sumatra. They live principally in the tree tops, where they construct a sort of nest for themselves. Orang-utans are about four and a half feet in height, and when walking, use their knuckles as well

FIG. 314. — Bengal macaque, an Old World monkey. (From Elliott. Courtesy American Museum of Natural History.)

as their feet. The brain of this species is more nearly like that of man than the brain of any other animal.

The *gorilla* inhabits the forests of western Africa. It is arboreal, feeds mainly on vegetation, has large canine teeth, reaches a height of five and a half feet and a weight of about five hundred pounds, walks on the soles of its feet aided by the backs of the hands, and is ferocious and untamable.

The *chimpanzee* (Fig. 317) also lives in West Africa. It resembles the gorilla, but has shorter arms and a smoother, rounder skull. It is easily tamed.

The *family Hominidæ* contains the single living species, *Homo sapiens*, or man. Man differs from the other primates

FIG. 315. — The hoolock, a gibbon. (From Elliott. Courtesy American Museum of Natural History.)

in the size of the brain, which is about twice as large as that of the highest monkey, and in his erect, bipedal locomotion. The hairy covering is not well developed, and the great toe is not

opposable. The mental development of man has enabled him to accommodate himself to every climate, and to dominate all other animals.

The human race may be divided into three primary groups: (1) the Negroid races, (2) the Mongolian, and (3) the Caucasian.

FIG. 316. — The Bornean orang-utan. (From Elliott. Courtesy American Museum of Natural History.)

The *Negroid races* possess frizzly hair, dark skin, a broad, flat nose, thick lips, prominent eyes, and large teeth. They are the African Negroes, the South African Bushmen, the Central African and Philippine Pygmies, the Melanesians, Tasmanians, and Australians.

The *Mongolian races* possess black, straight hair, a yellowish

skin, a broad face with prominent cheek bones, a small nose, sunken, narrow eyes, and teeth of moderate size. They are the inhabitants of northern and central Asia, the Lapps, Finns,

FIG. 317. — Chimpanzee. (From Elliott. Courtesy American Museum of Natural History.)

Magyars, Turks, Eskimos, Malay, brown Polynesians, and American Indians.

The *Caucasian*, or *white*, *races* possess soft, straight hair, a well-developed beard, retreating cheek bones, a narrow prominent nose, and small teeth.

CHAPTER XL

THE RELATIONS OF MAMMALS TO MAN

Domesticated Mammals. — The relations of mammals to man are varied and complex. In the first place, domesticated mammals are of almost inestimable value to man. *Cattle* raising is the most important animal industry in this country. Next in importance to cattle are *horses*. *Sheep* are utilized extensively for meat and wool. In some countries *goats* are used as draft animals and to furnish milk and meat. In the tropical countries of the Old World, especially in desert regions, the *camel* is the most important draft animal; its hair is valuable in the manufacture of fabrics and brushes. In parts of South America the *llama* and *guanaco* furnish the chief means of transportation. The *elephant* is in Asia used as a draft animal, for hunting, and for various other purposes; in Africa it is hunted for the ivory in its tusks.

The most common domesticated mammals are the dog, horse, ass, ox, sheep, goat, pig, and cat. The *dog* was probably the first mammal to be domesticated. Dogs have been the companions of man for many centuries; they have become changed while under domestication, until there are now more than two hundred breeds. In many cases local wild species of the genus *Canis* have been tamed; for example, the original Arctic sledge dogs were half-tamed gray wolves, and the dogs kept by our northwestern Indians were tamed coyotes.

The immediate ancestors of the *horse* are not known, and there are at the present time no wild horses from which it could have

arisen. It has probably developed from animals inhabiting the semiarid plains of central Asia.

The *ass* is the favorite beast of burden in Eastern countries. In this country the cross between a female horse and male ass is known as a *mule*. The common ass of Europe and America is descended, through the early Egyptian domestication, from the African wild ass.

The *oxen* of Europe and America were probably derived from the aurochs of Europe. The sacred or humped cattle of India doubtless developed from one of the wild races that still roam the Himalayan foothills.

Sheep have been domesticated for so many centuries that their ancestors are not known, but there are many wild sheep from which they may have originated. *Goats* have also been domesticated since the earliest times, and their wild relatives are abundant in many parts of the world.

The domesticated *pigs* are descended from the European wild boar and the Indian wild boar.

The common house *cat* has a complicated ancestral history. Its remote ancestor was probably the Egyptian cat from which the Mediterranean cat, the wildcat, the jungle cat, the steppe cat, and the Indian desert cat are descended. The European and American domesticated cats were derived either from the Egyptian cat or the Mediterranean cat, which soon became crossed with the wildcat. A number of crosses have been made between the various wild and domesticated cats, resulting in a large variety of mixed breeds.

Game Mammals. — The game mammals are those that are pursued and taken by sportsmen. Some of the more important game mammals of North America are the moose, wapiti, deer, bears, mountain lions, foxes, wolves, coyotes, wildcats, and rabbits. Some of these are exceedingly destructive, and certain states pay a bounty for their capture; others, like the deer, are of considerable value as food, though they may be injurious to farms in thickly populated districts. The various states pro-

tect many of the game animals during certain seasons of the year and in some cases for a period of years, so as to prevent their extermination.

The *deer*, including the elk, reindeer, or caribou, and moose, are the most important of the big animals in America. Only one of them, the reindeer, has been completely domesticated; other species, however, can be kept easily in parks or game preserves, and the constant demand for their flesh (venison) has suggested the possibility of rearing them for food.

The *Rocky Mountain elk* or *wapiti* (Fig. 306) at one time ranged over most of the United States, and ten million individuals were probably present then. They have been rapidly killed off, however, until now there are only a few outside of the Yellowstone National Park and neighboring country. In summer the herds in this Park number about thirty thousand. Partial provision for winter forage has been made by the government within the Park, but the supply is not enough, and many of the elk perish every winter. Elk meat is superior in flavor to most venison, but our laws prevent its sale, and so no efforts are made to rear these animals for market, although they can certainly be bred successfully in captivity.

The common *Virginia* or *white-tail deer* (Fig. 318) occurs almost all over this country and is therefore adapted to various habitats. It is claimed that there are within the United States 250,000,000 acres of land not suited to tillage or to the pasture of horses, cattle, or sheep on which deer and elk could be profitably reared. The chief obstacle to profitable propagation of deer in the United States is the restrictive character of state laws governing the killing, sale, and transportation of game. Many of the states, following precedent, lay down the broad rule that all the game animals in the state, whether resident or migratory, are the property of the state. A few states except game animals that are "under private ownership legally acquired." A few others encourage private ownership by providing a way in which wild animals — deer and the like — may be captured for

domestication. Generally, when private ownership of game is recognized by law, the right to kill such game is granted, but the owner is hampered by the same regulations as to season, sale, and shipment that apply to wild game. One by one, however, state legislatures are coming to recognize the interests of

FIG. 318. — Virginia or white-tail deer. (From U. S. Dept. of Agric.)

game propagators, and game laws are gradually being modified in accordance with the change of view.

Predaceous Mammals. — Predaceous mammals feed upon the flesh of other animals; if these animals are beneficial to man, the predaceous mammal may be considered injurious, but if the animals preyed upon are harmful to man, the predaceous mam-

mal is beneficial. The harmful predaceous mammals include the wolves and cougars, which subsist largely upon big game, sheep, cattle, and horses, and the house cat, which destroys millions of birds in this country annually.

The other predaceous mammals are occasionally harmful, but usually beneficial. Coyotes and wildcats, if poultry and sheep are properly protected, devote their attention to rabbits and other small mammals, and insects. The mink often commits depredations upon poultry, but more than pays for this by destroying meadow mice and muskrats. The weasel has a similar bill of fare. The skunk destroys immense numbers of mice, grubs, and noxious insects. The badger feeds largely upon ground squirrels and other burrowing mammals and insects.

Wolves and *coyotes* cause a loss to the stockmen and farmers of the United States of several million dollars annually, and in some of the Northern States they threaten the extermination of deer on many of the best hunting grounds. Many methods have been used to prevent these losses. Elk are persistent enemies of wolves, and a few of them are able to protect the flocks of sheep in a thousand-acre pasture. In many states bounties are paid for killing wolves and coyotes, but this has not resulted in their extinction. The best way of preventing their increase is to locate their dens and destroy the young each year. The dens are natural cavities in rocky ridges or in hollow logs. The wolves produce from six to ten young in a litter and the coyotes from five to nine. Traps and poisoned meat are also employed to capture or kill the adults. The stock in small pastures can be protected from these predaceous mammals by fences built so that they cannot get through.

The *fox* (Fig. 289), from its occasional misdeeds, is looked upon by the majority of mankind as a deep-dyed villain that devotes its entire life to robbery and derives all its forage from the chicken yard or duck pen. As a matter of fact, even in localities where foxes are abundant, it is comparatively rare that poultry is destroyed by them. On all well-regulated farms chickens

are housed at night, and the fox necessarily turns his attention to field mice, rabbits, ground squirrels, and insects, such as grasshoppers, crickets, and May beetles, to the great benefit of the farmer. Although it is true that the fox destroys a considerable number of birds, yet a ruffed grouse has been known to rear its young within 100 feet of a fox den, and the tracks of the young birds have repeatedly been seen on the fresh earth before the entrance. Among the food brought to the young of this litter and left outside were rabbits, mice, and a half-grown woodchuck, but no birds of any kind.

The fur of the fox is a very valuable article of commerce. In January, 1908, fox skins were quoted as follows: red fox, $1.50 to $3.50 each; cross fox, $4 to $8; silver fox, $50 to $250; and higher prices are sometimes paid for high-grade silver-fox skins. The silver fox is a color variety of the common red fox. Its fur is entirely black or more or less tipped with white. The rearing of foxes for the sake of their fur is now carried on in several localities, and undoubtedly fox farms will increase in number and importance as the supply of skins from wild animals decreases.

Fur-bearing Animals. — The majority of the fur-bearing animals of North America belong to the marten family. This family includes the otter (Fig. 292), mink, weasel (Fig. 293), marten, wolverine (Fig. 294), and badger. Most of these animals are now scarce, and furriers are forced to use the skins of other species, such as the skunk, muskrat, raccoon, fox, lynx, black bear, and rabbit. Of all the products derived from wild animals, furs are the most useful and valuable. Indispensable to primitive man, they are scarcely less important to the most civilized, for in warmth, beauty, and durability no manufactured fabrics excel them. But expanding civilization is steadily diminishing the supply of furs, both by increasing the demand and by encroaching upon the territory in which they are produced. Many furs, as well as ivory, whalebone, and other natural commodities, are already so scarce that the demand for them is met largely by the substitution of inferior products.

The three fur animals still fairly abundant in the United States are the muskrat, the mink, and the skunk. Of these the *muskrat* is most likely to retain its numbers, since it multiplies rapidly and, properly protected, is in no danger of extinction

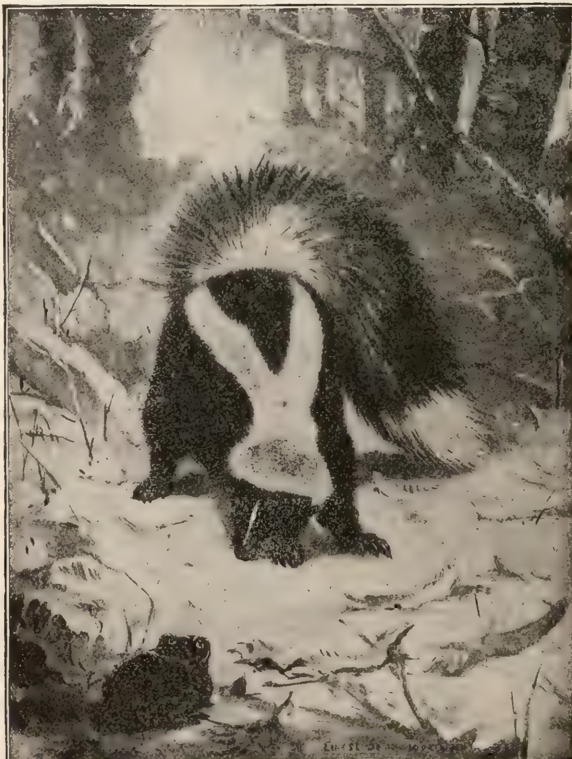

Fig. 319. — Skunk. (From Ingersoll.)

except where swamps are drained for agriculture. The *mink* breeds but once a year, and close trapping has already made it scarce over wide areas. Its choice of banks of streams and marshlands as a habitat aids in its preservation, but unless given more adequate protection it cannot long survive the high premium on

its pelt. The *skunk* (Fig. 319), although not yet in danger of extinction, is likely soon to be, since its pelt has great intrinsic value and the demand for it has not yet fully developed. Within a few years the price of its fur will probably be more than doubled.

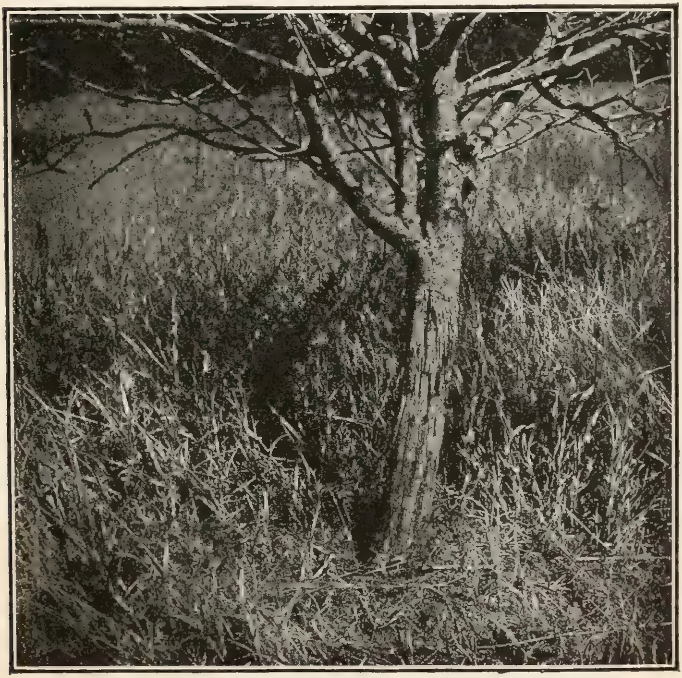

FIG. 320. — Apple tree killed by rabbits. (From Lantz.)

The three fur animals named are economically the most important ones, because each is widely distributed and adapted to a variety of climatic conditions. If, as is believed, they can be domesticated or successfully reared in captivity, their breeding may become a means of profit in most parts of the United States. The skunk, especially, presents possibilities of widely extended usefulness in domestication. At present it brings to the trappers of the United States about $31,000,000 annually.

Gnawing Mammals. — Gnawing mammals are, on the whole, injurious, since they include such notorious pests as the rabbits, rats, and mice. *Rabbits* are vegetarians, feeding on leaves, stems, flowers, seeds, buds, bark, and fruit. They damage especially clover, alfalfa, peas, cabbages, and the bark of trees. Young fruit, forest, and ornamental trees and shrubs in nurseries are subject to injury from rabbits, and frequently the branches and twigs within reach are cut off, or the bark is removed near the base of the trunk, thus girdling the tree and causing its death (Fig. 320).

Mice feed principally on stems, leaves, seeds, bulbs, roots, and other kinds of vegetation. A single field mouse devours in one year from twenty to thirty-six pounds of green vegetation, and a thousand mice in one meadow would consume at least twelve tons annually. Damage is done to meadows and pastures, to grains and forage, to garden crops, to small fruits, to nursery stock, to orchards, to forests trees, and to parks and lawns (Figs. 321 and 322).

"The *rat* is the worst mammalian pest known to man. Its depredations throughout the world result in losses amounting to hundreds of millions of dollars annually. But these losses, great as they are, are of less importance than the fact that rats carry from house to house and from seaport to seaport the germs of the dreaded plague." The amount of loss due to rats in the United States is not known; in Germany the loss is estimated at $50,000,000 per year. The losses in this country are as follows: a large part of the crops of cultivated grains is often destroyed by rats; "the loss of poultry due to rats is probably greater than that inflicted by foxes, minks, weasels, skunks, hawks, and owls combined"; rats are a serious pest in game preserves, feeding upon the eggs and young of pheasants, etc.; fruits and vegetables both before and after being gathered are damaged by rats; and miscellaneous merchandise in stores, markets, and warehouses suffers injuries second only to that done to grains. Rats eat bulbs, flowers, and seeds in

greenhouses, set fire to buildings by gnawing matches, depreciate the value of buildings and furniture, and are injurious in many other ways.

FIG. 321. — White-footed mouse and young. (Photo. by Dugmore. Copyright by Doubleday, Page and Co.)

Introduction of Foreign Mammals. — There is great danger in introducing mammals into this country. The brown rat reached this country about 1775, and is now, as pointed out above, our worst mammalian pest. Rabbits which were introduced into Australia about 1864 soon became so numerous that legislative action was taken for their destruction. The *mongoose* of India destroys rats, lizards, and snakes; it was introduced into Jamaica and other tropical islands and at first proved very beneficial, but later it became a great pest, destroying poultry, birds, young domesticated animals, and even fruit. These disastrous results from the introduction of foreign species of mammals led Congress to prohibit the importation of

most reptiles, birds, and mammals unless special permission is obtained from the Department of Agriculture.

FIG. 322. — Apple tree injured by meadow mice. (From Lantz.)

REFERENCES

See end of Chapter XXXVIII.

CHAPTER XLI

THE PROTECTION AND PROPAGATION OF WILD LIFE

IDEAS concerning the preservation of wild life have changed within the past forty years, for whereas formerly only sportsmen were anxious to maintain a constant supply of game for hunting purposes, now the general public is slowly coming to a realization that unless our birds and mammals are protected they will soon cease to exist. It is a well-established principle that it is our duty to preserve the wild life of to-day for the benefit of future generations. The steps necessary for such preservation are very simple and will not subject us to any particular hardships. Only three out of every one hundred inhabitants of this country are interested in killing birds and mammals, and this small proportion might still be allowed to hunt in moderation if proper laws were passed and enforced throughout the United States.

The Need of Protection. — There has been a constant decrease in the number of our birds and mammals ever since this country was colonized. Part of this decrease has been brought about by the ordinary effects of civilization, such as the building of cities, the cutting down of forests, and the draining and cultivation of land. Animals that have been driven away in this manner are, of course, lost to us, but we cannot be held responsible for their disappearance. Only a small proportion of them, however, have been eliminated in this way. Each year about half a million shotguns and five million cartridges are sold in this country for hunting purposes. In 1911, 1,486,228 hunting licenses were issued in twenty-seven of our states. Many persons, however,

hunt without licenses, and adding these together with those that hunt in the remaining states, an estimate of 2,600,000 is reached. This army of shooters annually kills off the natural increase as well as part of the original supply of game. The result is a noticeable decrease from year to year. It is reasonable to state that there is at present only about two per cent as much game as existed here fifty years ago.

Some of these hunters are more destructive than others, and all of them should not be condemned. The term "game hog" has of recent years been applied to those who kill more than a reasonable amount of game. Even worse than the game hog is the market hunter who kills birds and mammals by the thousands, which he sells either for food or for millinery purposes. "In a three months' shoot in Iowa and Minnesota, one market hunter killed 6250 game birds. In one winter's duck hunting in the South, he killed 4450 ducks. During his forty years' market hunting he killed 61,752 ducks, 5291 prairie chickens, 8117 useful blackbirds, 5291 quail, 5066 snipe, and 4948 plover. His grand total of slaughter was 139,628 game birds and sundries, representing twenty-nine species, several of them not game and useful."[1] Fortunately the sale of game has been stopped by law in many states, and will no doubt soon be discontinued throughout the entire country.

Several of the most notorious abuses of our wild life have been the destruction of the vast herds of bison (buffaloes) and the enormous flocks of passenger pigeons that once inhabited this country. The last wild buffalo of the United States outside of the Yellowstone National Park was killed in 1897. The original range of the buffalo extended from central New York to eastern Oregon and from northern Mexico to Great Slave Lake, nearly touching the Atlantic coast in Georgia and the Gulf coast in Louisiana. By 1730 the last buffalo east of the Alleghenies had been killed. By 1810 none were to be found east of the Mississippi. In 1870 those that were left were confined to two great

[1] Hornaday, *Wild Life Conservation.*

herds, the southern of which roamed the plains of eastern Colorado and New Mexico, southern Nebraska, western Kansas and Oklahoma, and northern Texas, while the northern herd ranged from northwestern Nebraska and western Dakota on the east to Montana and Wyoming on the west, and northward into Canada to the northern limit of the original range of the species. Twenty-seven years later not one was left in the United States except a few in captivity.[1]

"The passenger pigeon presents one of the marvels of bird life. A century ago, when the country was new and less settled, this bird, so wonderful for its gregarious habits, existed in flocks of such gigantic proportions that the numbers appear absolutely incredible. Thus Wilson, one of America's pioneer ornithologists, writing about 1808, estimated that a flock observed by him near Frankfort, Kentucky, contained not less than 2,230,272,000 birds, and Audubon five years later saw them at Henderson in the same state passing for three successive days in a practically continuous flock; 'the air was literally filled with pigeons, the light of noonday was obscured as by an eclipse,' and the rush of wings was 'with a noise like thunder.' Their nesting places were necessarily of great extent. One described by Wilson near Shelbyville, Kentucky, was several miles in breadth and extended through the woods for upward of forty miles. Every tree of suitable size was loaded down with nests, a large hemlock, for example, often holding from twenty to forty.

"With the advent of the white man in this country, and the blessing of civilization, the war upon the pigeon has been unceasing! Whenever a roosting or nesting place was discovered it was resorted to by a small army of despoilers, and with guns, poles, clubs, sulphur pots, and nets the work of destruction proceeded. Frequently from fifty to one hundred dozen were taken at a single throw of the net. At the large Michigan nesting it was estimated that five hundred netters were at work and their average catch was 20,000 birds apiece, while for another resort

[1] *The Game Market of To-day.*

it was estimated that hardly less than 1,000,000,000, including those dead and wounded but not secured, and the myriads of squabs left dead in the nest, were 'sacrificed to Mammon' during a single year."[1]

Such wanton destruction as this rapidly leads to extermination. Many species which have been exterminated over certain areas where they were once abundant, are still present elsewhere. For example, in Ohio the elk, bison, white-tailed deer, beaver, and wild turkey have all been destroyed. Other species have been persecuted to such an extent that only a few accidental stragglers remain in remote localities; these species have been practically exterminated. A few animals now exist in captivity, but the species has been exterminated in its wild state. This is true of the passenger pigeon and Carolina paroquet. Among the birds that have become wholly extinct within the past seventy years are the great auk, Labrador duck, and Eskimo curlew.

Protective Measures. — The need of protection is obvious to every one who studies the history of our wild life, and each should do his best to protect the animals so far as he is able. This, however, is not sufficient, and laws must be passed to prevent the extermination of the birds and mammals that are still left to us. The most important laws are the Lacey bird law, the Bayne law, the McLean-Weeks law, and the plumage law.

The *Bayne law* prohibits the sale of all American wild game in New York State. The *McLean-Weeks law*, or *federal migratory bird law*, which was passed by Congress in 1913, prohibits spring shooting of migratory birds, provides a closed season for most of our shore birds, and shortens the open season for water fowl. The *plumage law* is part of the new (1913) tariff bill. It stopped the importation of the feathers or skins of all wild birds except the ostrich. The *Lacey bird law*, which was passed in 1900, deals with the introduction of game animals into this country and the interstate commerce in game.

[1] Knowlton, *Birds of the World.*

The Propagation of Wild Life. — Besides the efforts that have been made to protect wild life, attempts are constantly on foot to increase the number of birds and mammals. The introduction of foreign species is unnecessary, since our native animals will restock the country if given the opportunity. Furthermore, foreign animals often become pests when introduced, for example, the English sparrow in the United States, the mongoose in Jamaica, and the rabbit in Australia.

The National Parks, such as the Yellowstone, Glacier, and Grand Cañon National Parks, have become natural refuges for our persecuted game animals, since here they are fully protected. "The most conspicuous of all cases of the recognition of protection by wild animals is to be found in the Yellowstone Park. This feeling of security is shared by nearly all the wild animals of the Park, but it is most strikingly displayed by the herds of mule deer, antelope, and elk that make their home near Fort Yellowstone and the Mammoth Hot Springs. In winter the mule deer and antelope are fed on hay on the parade ground, as if they were domestic sheep and cattle. At Ouray, Colorado, bands of mountain sheep pose for photographs at short range, in the town, in a manner that to every hunter of that wild and wary species is a profound surprise.

"The Yellowstone Park grizzlies, and black bears also, are no exceptions to the general influence of peace and protection. These bears are now famous for the thorough and practical manner in which they have accepted protection, and for years have been reaping the benefits of it. They have become confirmed grafters. They not only make daylight visits to the garbage heaps at the hotels, but they have been known to enter the hotels and walk about in them, looking for offerings of food." [1]

That native animals will soon become abundant under protection in localities where they were once numerous may well be illustrated by the restocking of Vermont with white-tailed deer. "In the beginning, the people of Vermont exterminated their

[1] Hornaday, *Wild Life Conservation.*

original abundant stock of white-tailed deer. In 1870, the species was, so far as known, practically extinct throughout that state. In 1875, a few business men of Rutland decided to make an attempt to restock with deer the open forests around that city. Accordingly they went to the Adirondacks, procured seven female and six male white-tailed deer, took them to a forest six miles from Rutland, and set them free.

"Those deer took kindly to their new home, persisted and proceeded to stock the state. None were killed, save a few that were shot contrary to law, for twenty-two years.

"In 1897, it was decided that Vermont's deer had become sufficiently numerous and well established so that deer hunting might begin; but on bucks only. In that year 150 head were killed, and during the next three years about the same number were taken annually. In 1901, 211 were killed; in 1902, 561; in 1905, 791; in 1907, 1600; in 1908, 2208, and in 1909, the grand total was 5261. The total weight of venison taken was 716,358 pounds. Computed at the lowest reasonable valuation, twelve cents per pound, the total value for 1909 would be $85,962" (Hornaday).

Many organizations are now engaged in the propagation of wild life. The federal government has established the Bureau of the Biological Survey, and has protected the game within the National Parks. The next step in the progress of the work should be a similar protection of the game in our National Forests. The state governments have appointed commissions for the protection and propagation of game, and many game farms have been established where animals are raised for the purposes of distribution throughout the states. Besides this there are a few private preserves in this country.

Among the national organizations interested in game protection are the American Bison Society, the American Ornithologists' Union, the Campfire Club of America, the League of American Sportsmen, the National Association of Audubon Societies, and the New York Zoological Society.

Apparently it is an easy matter to get the necessary laws passed as soon as the general public is made to realize the present condition of our wild life. It is one of the chief functions of the organizations mentioned above to distribute a knowledge of the value of protecting and propagating wild animals. It is the duty of every one to help in this work, and no chance of aiding in this great cause should be allowed to escape. No better example of the results of a lack of education can be cited than that of the campaign against the hawks in Pennsylvania.

"In 1885, the rural feeling against hawks and owls reached the high-water mark in Pennsylvania. In response to the demands of the farmers of the state, the Pennsylvania legislature enacted a law providing a bounty of fifty cents for the heads of hawks and owls. Naturally, great slaughter of these birds ensued. In two years, 180,000 scalps had been brought in and $90,000 had been paid out for them.

"The awakening came even more swiftly than the ornithologists expected. By the end of two years from the enactment of 'the hawk law,' the farmers found their fields and orchards thoroughly overrun by destructive mice, rats, and insects; and again they went clamoring to the legislature, this time for the quick repeal of the law. With all possible haste this was brought about; but it was estimated by competent judges that in damages to their crops 'the fool hawk law' cost the farmers of the state of Pennsylvania more than $2,000,000" (Hornaday).

As noted in Chapter XL, there are a number of animals that may be considered pests. These should, of course, be kept under control. For reasons of sentiment they should not be entirely exterminated, but their numbers may be reduced to such an extent that they can do very little if any real damage.

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CHAPTER XLII

THE CONSERVATION OF OUR NATURAL RESOURCES

In the preceding chapters the principal groups of animals in the animal kingdom have been considered from several standpoints. We have learned that animals all need certain things, such as *protection* from physical injury and from their enemies, *food* for furnishing the power to carry on activities and to grow, air for the *oxygen* necessary to release this power by oxidation, and the ability to *reproduce* others of their kind to prevent the race from dying out. We have also learned the methods used by different kinds of animals in satisfying these needs and the structures and physiology of the organs employed. This knowledge is necessary before we can understand the relations of animals to man and how we can eliminate harmful species and encourage beneficial species. Throughout our studies this economic or applied phase of our subject has been emphasized. Still another viewpoint is possible, however, and that is *the relations between animals and the community in which we live*, or between animals and the state or nation. This is a part of our subject that has also been emphasized in the preceding chapters.

The problems presented by one city in most cases differ somewhat from those of other cities. A seacoast community may be vitally interested in the fishing industry; in a cattle raising country a detailed knowledge of animal parasites and their control is essential; and birds and insects are important everywhere, but the species differ and must be dealt with accordingly. What groups of animals should be studied in detail depends

largely therefore upon the locality, but the general principles that have been included in our studies can be applied everywhere.

The country in which we live was at the time of its settlement perhaps the most richly endowed with what are called natural resources of any in the world. Vast areas were covered with forests; large, rapidly flowing rivers were ready to deliver their power to whoever wished to use it; the soil was rich in plant food and the climate suitable for agricultural pursuits; extensive deposits of coal and other minerals were waiting to be mined; the rivers, lakes, and surrounding seas were alive with fish, oysters, lobsters, and other "sea food"; the woodlands and prairies abounded with bobwhites, prairie chickens, and other game birds; the Great Plains were thickly dotted with huge droves of bison, deer, elk, moose; other game animals were everywhere abundant, and fur-bearing animals could be obtained with ease.

Only within recent years has any attention been directed toward our methods of using these "inexhaustible" resources. In 1908 the congress of the governors of all the states and territories met to consider the question of conservation which President Roosevelt considered "as the weightiest problem now before the nation, as nobody can deny the fact, that the natural resources of the United States are in danger of exhaustion, if the old wasteful methods of exploiting them are permitted longer to continue. The enormous consumption of these resources, and the threat of imminent exhaustion of some of them, due to reckless and wasteful use, once more call for common effort and common action."

The truth of this statement can easily be established. *Lumbering* has been carried on without regard to the future. *Water power* is continually wasted because it is not utilized. In many countries such as China, Spain, Greece, and Palestine large tracts are *bare of soil* where once were flourishing fields of grain. Similar conditions exist in some parts of the United States and threaten to occur in others. Our principal *mineral resources* are

coal and iron; others are petroleum, natural gas, lead, zinc, gold, silver, and stone. The methods of mining these minerals, and of using them after they are mined, are extremely wasteful.

Throughout this book an attempt has been made to indicate the value of *animals as a natural resource*. The bisons have been practically exterminated; millions of passenger pigeons have been destroyed until not a single one remains alive to-day; the elk, pronghorn antelopes, mountain sheep, and other big game animals which were formerly abundant have decreased so greatly that now very few exist outside of zoological parks; the alligators, the seals, and the whales have been killed without regard to the future; our game birds and insectivorous birds have been persecuted and hordes of insects thus let loose upon our fields and orchards; the terns, humming birds, and egrets are destroyed for their plumes; our waters are rapidly being depleted of fish, oysters, lobsters, etc.; and finally even human lives are sacrificed because of the neglect of opportunities to promote health by preventing the dissemination of disease germs.

Practical zoology is concerned with the conservation of our natural resources so far as they are influenced by animals. What can be done to prevent the waste of human lives has been indicated in the crusades against the house (typhoid) fly and the yellow fever mosquito. Some of the efforts of the national, state, and city governments to prevent the destruction of useful animals have likewise been described in connection with the song birds, fish, and game. Attempts to stem the tide of destruction have been made and are now in progress, as indicated by the review of the work being done by some of our scientific institutions, as presented in Chapters XLI and XLIII. This review indicates what our thoroughly enlightened people are trying to do for the conservation of some of our natural resources.

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CHAPTER XLIII

THE PROGRESS OF ZOOLOGY

It is difficult to realize at this stage in the world's history that what to us are well-known facts were entirely unknown to the men of past centuries. Zoological facts that are now common knowledge had to be laboriously worked out and established — a process that has occupied the attention of thousands of men for many centuries. Progress at first was very slow, but the more we know the easier it is to advance, and hence zoology and other sciences are moving forward more rapidly now than ever before.

Many of the most important scientific discoveries are connected with the names of certain men, and perhaps there is no better way of presenting a brief résumé of the history of zoology than by referring to a few of the scientists who have added the most to our zoological knowledge.

Aristotle (384–322 B.C.). — No one knows when man began to study animal life. The pursuit of certain forms for food, the domestication of others, and the practice of animal sacrifice doubtless furnished some crude and scattered notions of anatomy, physiology, and ecology, even in remote antiquity. The first scientific treatises that had an influence upon modern zoological ideas were not written until about three hundred and fifty years before Christ. At this time Aristotle's works appeared, and so careful were the observations of this remarkable man that they were considered authoritative for twenty centuries.

Aristotle was the foremost pupil of Plato and the tutor of Alexander the Great. His greatest works were on the natural

history of animals, the parts of animals, and the development of animals. They reveal a remarkable familiarity with the facts of comparative anatomy, physiology, and embryology. He was a critical compiler, and, from the fabric of scattered facts and fancies which existed at his time, produced a compact and fairly accurate account of animals.

Middle Ages. — The Middle Ages are a blank, so far as zoological progress is concerned. Superstition was rampant, and the belief in various fabled animals was prevalent. All zoological questions were referred to the ancient authorities, and original investigation was at a standstill. In one controversy a series of papers was published with respect to the number of teeth in a horse's mouth. In this instance not one of the writers seems to have thought of examining an animal, but all were satisfied to quote the words of men who had died centuries before.

Linnæus (1707–1778). — After the intellectual awakening of the sixteenth century, naturalists no longer tried to cover the entire field of zoology, but restricted themselves to certain phases of the subject. Thus the Swedish scientist, Linnæus, chose systematic zoology as a specialty and attempted to describe all the existing species of animals and plants. He succeeded in listing 4378 in the tenth edition of his greatest work, *Systema Naturæ*. His great influence, and the wide recognition which was accorded his work, made the systematic side of zoology the most active field of investigation for a long time after his death. The aim of the systematic zoologist has been to describe all the species of animals, and to arrange them according to a natural system, *i.e.* a system that will show their true relationships to one another.

Cuvier (1769–1832). — Systematic zoology led to careful comparisons of the structures of one species of animal with those of others, causing the development of the science of comparative anatomy. One of the greatest comparative anatomists was the French scientist, Cuvier, who extended his studies over

the entire animal kingdom, and added a great mass of personal observations to the many descriptions published by his predecessors. Besides a number of treatises on comparative anatomy, he wrote a book on the fossil remains of animals, which founded the science of vertebrate paleontology. Among Cuvier's more noted successors were the Englishmen, Richard Owen (1804–1892) and Thomas H. Huxley (1825–1895), and the American, E. D. Cope (1840–1897).

Johannes Müller (1801–1858). — The study of structure, both of adults and of embryos, was accompanied by attempts to determine the functions of organs. Harvey made his name immortal by the discovery of the circulation of the blood. Haller (1708–1777) helped the science of physiology by summing up the principal facts and theories of his predecessors. Johannes Müller founded modern comparative physiology, and prepared a handbook of the physiology of man, based upon the personally verified statements of others and upon his own observations, which to this day has no equal. He made use of the microscope, and brought to his work a knowledge of physics, chemistry, and psychology. Since his time physiological investigations have progressed along physical and chemical lines, and vital activities are now explained by many in physico-chemical terms.

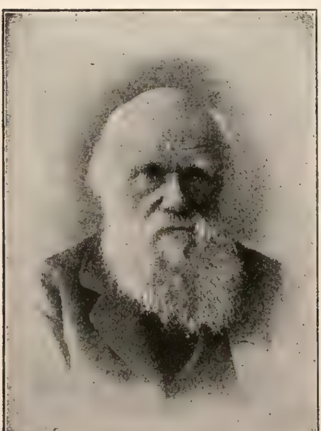

FIG. 323. — Charles Darwin. (From Davenport.)

Charles Darwin (1809–1882). — The ideas of special creation and spontaneous generation which were once widespread were replaced during the last century by the theory of organic evolution, largely through the writings of Charles Darwin (Fig. 323).

The theory of special creation is that all animals were in the beginning created by some omnipotent being. That of spontaneous generation holds that animals arise directly from inorganic substances; for example, ancient naturalists believed that frogs and toads arose from the muddy bottom of ponds under the influence of the sun, and that insects originated from the dew.

Darwin's book, *The Origin of Species by Means of Natural Selection*, which appeared in 1859, placed the theory of organic evolution on a firm foundation. At the present time practically all zoologists believe that animals can arise only from preëxisting animals by reproduction, and that by changes of some sort complex animals have evolved from simpler species. Arguments in favor of this belief have been derived from the study of comparative anatomy, physiology, embryology, classification, geographical distribution, and of fossil remains of animals that are found embedded in the earth's crust. At the present time zoologists take for granted that evolution has occurred, but are actively engaged in efforts to discover how it has taken place.

Gregor Mendel (1822–1884). — One method of attacking the subject of evolution is to study heredity; that is, the study of the similarities of and differences between parents and their offspring. This is especially effective when animals or plants of different kinds are bred together. At the present time the foremost law of heredity is that discovered by Mendel (Fig. 324), a monk who lived in an Austrian monastery. Mendel crossed different kinds of peas and found that the offspring all resembled one of the parents. When these offspring were interbred, however, three fourths of their offspring resembled one grandparent and one fourth resembled the other grandparent. This and other facts discovered by Mendel have been found to hold true for many animals as well as plants and constitute what is known as Mendel's law.

Pasteur (1822–1895). — There are two kinds of science

usually recognized, pure science and applied science. Pure science deals with facts without regard to their practical value to mankind. Applied science applies the facts of pure science

Fig. 324. — Gregor Mendel. (From Punnett.)

in such a way as to benefit mankind. Thus pure science comes first and is necessary before anything practical can be accomplished. Occasionally, however, a scientist appears who is

able to combine the two; such a one was Louis Pasteur (Fig. 325).

Pasteur was born at Dole in eastern France in 1822. He was particularly interested in chemistry, but is most famous because of his contributions to biology. His first investigations were concerned with the phenomena of fermentation and decay. By proving that only living microorganisms (yeast and bacteria) can cause fermentation, he was able to suggest a method of preventing this process by heating substances to a temperature high enough to kill these germs. This method of killing germs is now known as pasteurization and has saved billions of dollars and thousands of lives since milk and other liquids can be preserved in this way.

Pasteur's attention was next called to a silk-worm disease which was killing off the silkworms in France and Italy and thus destroying a very important industry. By long investigations he proved that certain germs in the eggs, larvæ, pupæ, and adults were responsible for the trouble, and by suggesting a scientific method of control succeeded in eradicating the disease.

The Pasteur Institutes that now exist in many cities throughout the civilized world have for their object the treatment of hydrophobia. This disease was found by Pasteur to attack the nervous system of victims bitten by mad dogs and other animals. The treatment was also discovered by him. It consists in first burning (cauterizing) the wound with strong nitric acid and then injecting into the patient a specially prepared solution (virus) every day for three weeks. Of over 20,000 cases treated in Paris less than one per cent have died.

Pasteur's discoveries were extremely important from the standpoint of both pure science and applied science. They also led more or less directly to discoveries made by his contemporaries and followers. Among these are Lister's treatment of wounds by means of antiseptics and Roux's and Behring's antitoxin for diphtheria.

Zoological Progress of To-day. — There are many zoologists

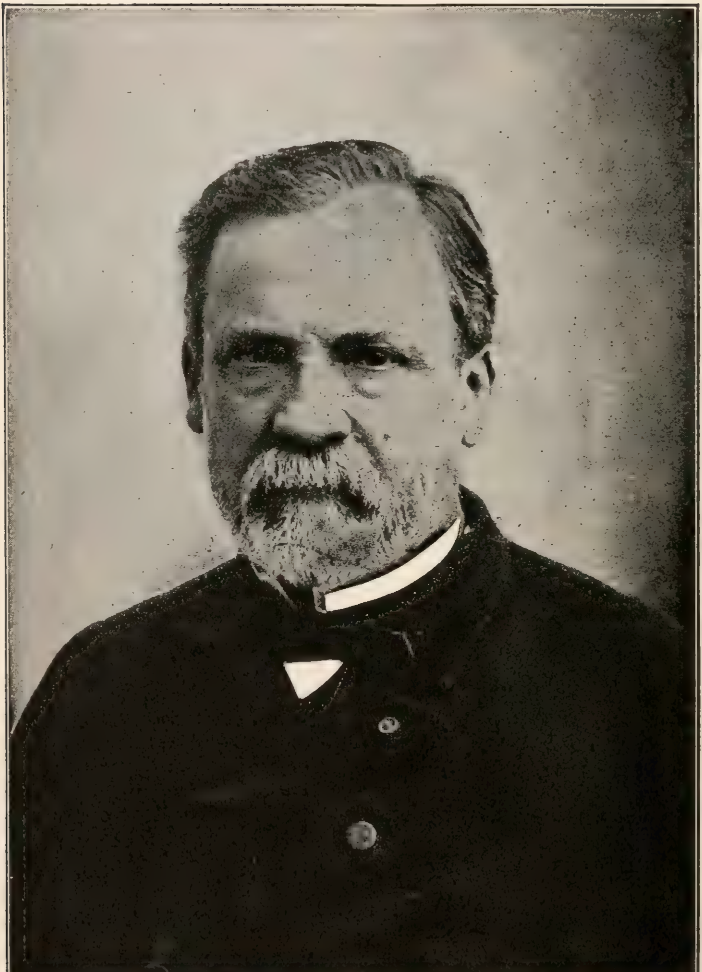

FIG. 325. — Louis Pasteur. (From Peabody and Hunt.)

now living who will no doubt in the next generation be ranked with those mentioned in the preceding paragraphs. These men, their associates, and their students are all engaged in adding to the sum of human knowledge so far as animals are concerned. They are for the most part at work in universities, museums, endowed institutions, or government institutions.

The professors in nearly all universities are encouraged not only to distribute knowledge by teaching, but also to add to our knowledge by carrying on original investigations. The results of these investigations are published in scientific magazines such as the Journal of Morphology, the Journal of Experimental Zoology, the Biological Bulletin, the American Naturalist in this country and in the many foreign magazines of a similar nature.

Natural history museums are often considered simply places where stuffed animals are exhibited, but the best museums employ capable scientists who spend all of their time working over the collections and publishing the results of their researches. Some of the large museums in this country are the National Museum in Washington, D.C., the Museum of Comparative Zoology in Cambridge, Massachusetts, the American Museum of Natural History in New York City, the Philadelphia Academy of Sciences in Philadelphia, Pennsylvania, the Carnegie Museum in Pittsburgh, Pennsylvania, and the Field Museum in Chicago, Illinois.

There are very few endowed institutions for the advancement of science, but those that have been established within recent years in this country have accomplished a great deal for the progress of science, both pure and applied. The largest of these are the Carnegie Institution in Washington, D.C., and the Rockefeller Institute in Brooklyn, New York.

The meeting place of the sea and land is especially rich in the number of animals that have selected it as a habitat. It is not strange therefore to find zoologists studying at the seashore. There are several laboratories on our eastern coast and several

on our western coast. The largest of these is the Marine Biological laboratory at Woods Hole, Massachusetts (Fig. 326). Here several hundred men and women gather every summer for the purpose of studying the animal life of the sea and of discussing the facts and theories of zoology.

The government institutions where scientific work is carried on are devoted largely to applied science. Besides the work

FIG. 326. — The marine biological laboratory at Woods Hole, Mass.

done by the United States Department of Agriculture at Washington there are experiment stations scattered about throughout the country, usually connected with the state agricultural colleges.

The United States Department of Agriculture is the largest institution in this country devoted to the task of adding to our knowledge of plants and animals and of distributing this knowledge among the people. During the year 1913, 14,478 persons were employed by this department and over twenty million dollars were spent to carry on its work. The scientific bureaus in the department are as follows: —

Weather bureau	Bureau of animal industry
Forest service	Bureau of plant industry
Bureau of soils	Bureau of biological survey
Bureau of chemistry	Office of experiment stations
Bureau of statistics	Bureau of entomology
Office of public roads	

The bureau of animal industry, bureau of biological survey, and bureau of entomology are especially interested in animals.

Four series of publications are distributed by the Department of Agriculture: (1) popular and semi-technical bulletins dealing with the results of investigations; (2) the Journal of Agricultural Research for scientific papers, and the Experimental Station Record; (3) Farmers' Bulletins containing "specific directions for doing things"; and (4) annual reports, etc. Besides this the newspapers throughout the country are supplied with "brief popular statements of facts," and news letters are weekly sent out to more than 50,000 crop correspondents and farmers. Literature on almost any subject dealing with the rearing of animals and plants and the control of pests can be obtained free of charge by writing to the Secretary of Agriculture, Washington, D. C.

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